Climatology

Temperature & Pressure Belts of The World

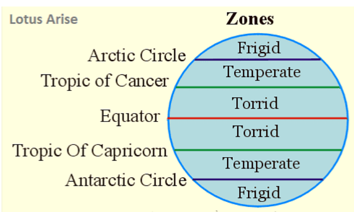
The Sun is the **primary source** of temperature in the atmosphere. However, the atmosphere only receives a small portion of heat energy directly from the Sun, as most of its energy comes from the long-wave radiation emitted by the Earth.
The heating and cooling of the atmosphere are achieved through a combination of direct solar radiation and the transfer of energy from the Earth. This energy transfer occurs through processes such as conduction, convection, and radiation, which help to regulate atmospheric temperature.

Temperature belts of world

The Earth is divided into three primary heat zones, largely determined by their proximity to the Equator. These zones are:

- **Temperate Zone:** This zone experiences moderate temperatures and is located between the Tropics and the Polar Circles, extending roughly from 23.5 to 66.5 degrees latitude in both the Northern and Southern Hemispheres.
- **Torrid Zone:** Also known as the Tropical Zone, this region is the hottest and is situated near the Equator, ranging approximately from 23.5 degrees North to 23.5 degrees South latitude.
- **Frigid Zone:** This is the coldest zone and is situated near the poles, spanning roughly from 66.5 degrees to 90 degrees latitude in both the Northern and Southern Hemispheres.

These heat zones are primarily influenced by the angle at which the sun's rays strike the Earth's surface, with the Torrid Zone receiving the most direct sunlight and the Frigid Zones receiving the least.



Temperature Belts

1. **Torrid Zone (Tropical Zone)**
   The tropical zone, also known as the torrid zone, is the warmest region on Earth. It stretches from the Tropic of Cancer at 23.5°N latitude, across the Equator at 0° latitude, to the Tropic of Capricorn at 23.5°S latitude. Within this zone, the Sun's rays directly reach the Earth's surface at least once a year, resulting in consistently high temperatures.
2. **Temperate Zone**
   The temperate zones are the Earth's regions with moderate and comfortable climates. There are two temperate zones, one in each hemisphere, located between 23.5° and 66.5° latitude. These areas experience generally mild temperatures and distinct seasons, making them suitable for human habitation.
3. **Frigid Zone**
   The frigid zones are the coldest regions on Earth, characterized by harsh and freezing temperatures. They are situated to the north of the Arctic Circle at 66.6°N latitude and to the south of the Antarctic Circle at 66.5°S latitude. These areas are perpetually covered in ice, and sunlight is scarce or even nonexistent for extended periods throughout the year.

Which of the following factors does NOT influence temperature distribution across the Earth? A. Latitude **B.** Altitude **C.** Proximity to water bodies **D.** Distance from the Moon

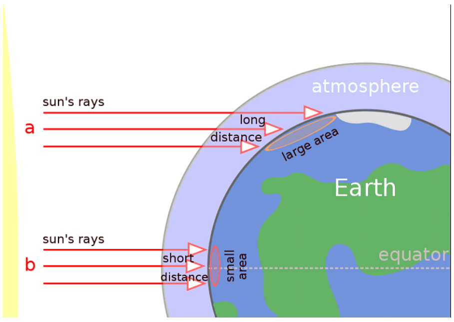
Importance of the Heat Zones

The importance of heat zones lies in their role in helping us understand climate changes and study weather conditions across the world.**Several factors influence temperature patterns on the globe, including:**

- Latitude
- Altitude
- Proximity to oceans and seas
- Local wind effects
- Continentality (distance from large water bodies)
- Slope aspect (the direction a slope faces)

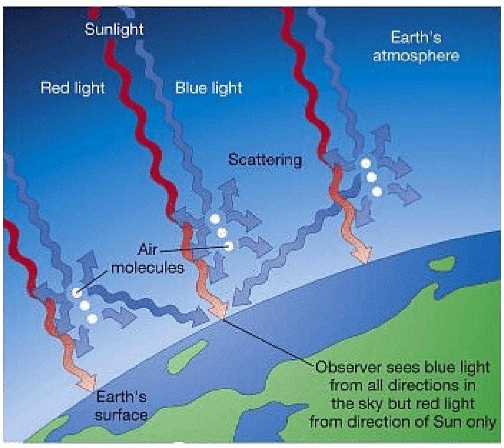
Latitude plays a significant role in temperature distribution across the Earth. Temperatures are generally higher at or near

the **Equator** and decrease as one moves towards the North and South Poles. The reason for this pattern is due to the Earth's curvature, which causes the Sun's rays to strike different parts of the Earth's surface at varying angles. At the Equator, the Sun's rays hit the Earth's surface at a 90° angle (angle of incidence), while the angle decreases as one moves towards the poles. This results in a more concentrated and intense heating effect at the Equator, while the heating effect is more spread out and weaker closer to the poles.



Transparency of Atmosphere

- Aerosols, like smoke and soot, dust, water vapor, and clouds, can impact the transparency of the atmosphere. This is because these particles can interact with radiation in various ways, depending on the size of the particles and the wavelength of the radiation.
- When the wavelength of radiation is larger than the size of the obstructing particle (e.g., a gas molecule), scattering of radiation occurs. On the other hand, if the wavelength is smaller than the obstructing particle (e.g., a dust particle), total reflection takes place.
- Certain particles, such as water vapor, ozone molecules, carbon dioxide molecules, and clouds, can also absorb solar radiation. This means that these particles capture the energy from the radiation and prevent it from passing through the atmosphere.
- It is important to note that most of the light that reaches the Earth's surface is scattered light, which has been deflected by particles in the atmosphere. This is why the sky appears blue, as shorter blue wavelengths are scattered more easily than longer red wavelengths.



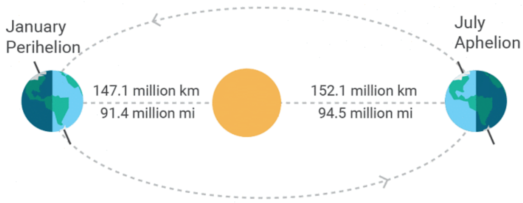
Scattering by Temperature

Land-Sea Differential

- The albedo, or the reflecting ability, of land is significantly higher than that of oceans and water bodies. This is particularly true for snow-covered areas, which can reflect up to 70%-90% of incoming sunlight (insolation).
- Sunlight is able to penetrate deeper into water, reaching depths of up to 20 meters, compared to land where it only penetrates up to 1 meter. As a result, land experiences more rapid heating and cooling compared to oceans. In the ocean, a continuous convection cycle aids in the exchange of heat between layers, which helps to maintain lower diurnal and annual temperature ranges.

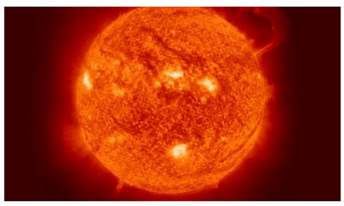
Earth's Distance form Sun

- During its orbit around the sun, the Earth reaches its farthest point from the sun, called aphelion, on July 4th at a distance of 152 million kilometers. Conversely, the Earth is closest to the sun on January 3rd at a distance of 147 million kilometers, which is known as perihelion. As a result, the Earth receives slightly more solar energy, or insolation, on January 3rd compared to July 4th.
- However, this variation in the amount of solar energy received by Earth does not significantly impact daily weather changes on its surface. This is because other factors, such as the distribution of land and sea as well as atmospheric circulation, play a more dominant role in influencing weather patterns. Thus, the difference in solar output between aphelion and perihelion is not a major factor in determining daily weather conditions on Earth.



Sunspots

Sunspots are formed on the outer surface of the sun due to periodic disturbances and explosions. These sunspots fluctuate in number from year to year, following an 11-year cycle. As the number of sunspots increases, so does the energy radiated from the sun. Consequently, the amount of solar radiation, or insolation, received by the Earth's surface also increases.



Sun

Altitude

- altitude is the height above the sea level

- high altitude (at the mountain), low temperature
- low altitude (on the land surface), high temperature

Reasons

- at the higher altitudes, the amount of atmosphere decreases and as a result, there is less water vapour in the air. the atmosphere absorbs less heat and therefore the temperature at higher altitude drops.

Distance from the Sea

- the difference in heating of land and water affects the temperature of places located near the coast differently from those located inland.

Maritime Influence

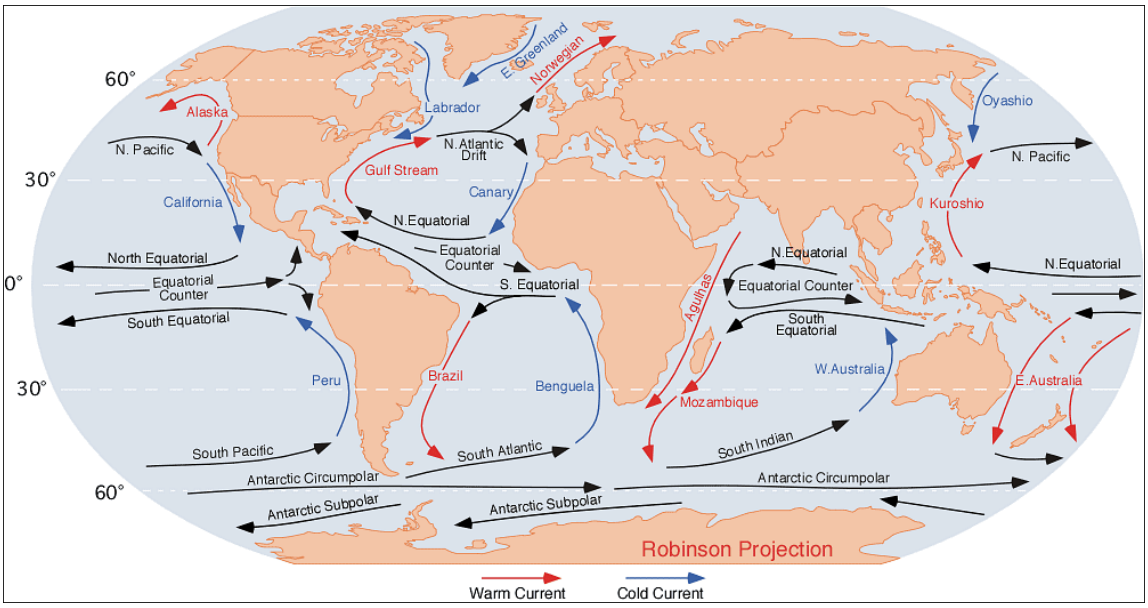
- when the sea is cooler than the land in summer, it lowers the temperature of the coastal place. however, during the winter the sea is warmer than the land and keeps coastal places warmer by moderating the winter temperature.

Continental Influence

- located in the interior of large continents or landmasses are under the continental influence, that is, the sea does not an effect on them as they are too far in temperatures. as the land heats up rapidly, inland locations tend to have hotter summers than areas near the coast in similar latitudes.

Ocean Currents

- Ocean currents are vast streams of water that flow through the oceans, created by winds blowing across the water's surface. There are two primary types of ocean currents: cold currents, which transport water from the polar regions, and warm currents, which bring warm water towards the polar regions.
- These ocean currents have a significant impact on the temperature of nearby coastal areas. For instance, coastal regions influenced by warm currents will experience milder temperatures during winter months. On the other hand, if cold currents travel along the coast, they can cause temperatures in the area to drop.
- In summary, ocean currents play a crucial role in regulating temperatures in coastal regions by transporting warm and cold water from different parts of the world.

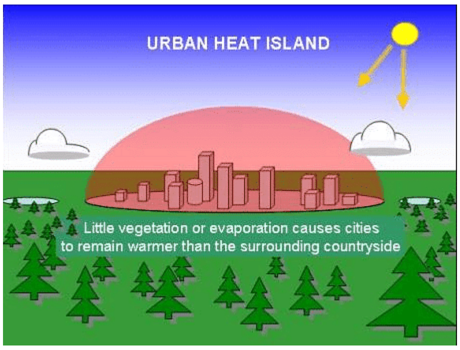


Ocean Currents

Types of land surface

- Dense forest– the vegetation prevents solar radiation from reaching the ground directly. The ground remains cool.

- In the city– the presence of concrete surfaces tends to keep the air temperature high. The concrete surface absorbs heat during the day and retains the heat at night.

- 

- Urban Heat Island

Aspect

- Aspect refers to the orientation of a slope in relation to the sun's position. It determines the amount of sunlight a slope receives, which affects its temperature.
- In tropical regions, aspect is not very significant because the sun is usually high in the sky during mid-day, resulting in relatively uniform solar radiation across all slopes. Thus, the impact of aspect on temperature is minimal in these areas.
- However, in temperate regions, the sun's angle is much lower during winter, causing differences in temperature between slopes that face north and south. In the northern hemisphere, south-facing slopes receive a higher concentration of solar radiation, making them generally warmer than north-facing slopes. This is due to the fact that the sun's rays directly hit the south-facing slopes, resulting in more absorption of sunlight and higher temperatures.

Mean Annual Temperature Distribution

- **Isotherm:** An imaginary line joining places having equal temperatures.
- The horizontal or latitudinal distribution of temperature is shown with the help of a map with isotherms.
- The effects of altitude are not considered while drawing an isotherm. All the temperatures are reduced to sea levels.

General characteristics of isotherms

- Isotherms generally follow the lines of latitude, which means that they run parallel to each other. This is because locations at the same latitude receive roughly the same amount of sunlight, resulting in similar temperatures.
- However, there can be sudden bends in isotherms at the boundaries between oceans and continents. This is due to the different ways in which land and water absorb and release heat, which causes variations in temperature even at the same latitude.
- When isotherms are closely spaced, it indicates a rapid change in temperature, or a high thermal gradient. On the other hand, when isotherms are widely spaced, it suggests that the temperature change is small or slow, resulting in a low thermal gradient.

General Temperature Distribution

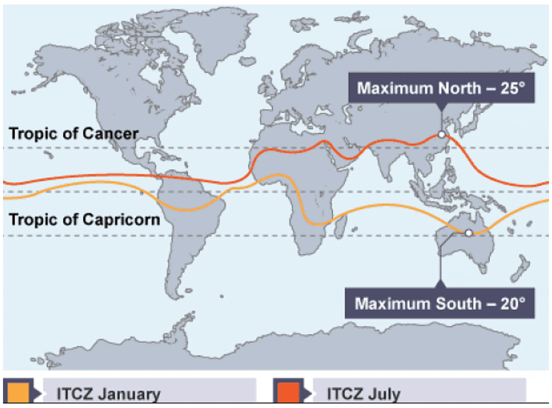
- The highest temperatures are typically found in tropical and subtropical regions due to the high levels of sunlight they receive. In contrast, the lowest temperatures are generally observed in polar and subpolar regions, as well as in continental interiors where the moderating effects of oceans are absent.
- The range of temperatures experienced throughout the day (diurnal range) and the year (annual range) is greatest in the interiors of continents, again due to the absence of the ocean's moderating effects. On the other hand, the diurnal and annual range of temperatures is smallest in oceans, as the high heat capacity of water and its mixing properties help to maintain a more consistent temperature.
- Temperature gradients, or the rate at which temperature changes with distance, are generally low in tropical regions since the sun is nearly overhead all year long, while higher gradients are found in middle and higher latitudes where the sun's path varies significantly throughout the year. Additionally, temperature gradients tend to be low on the eastern edges of continents due to the presence of warm ocean currents, whereas they are high on the western edges where cold ocean currents prevail.
- The distribution of isotherms, or lines of equal temperature, is irregular in the northern hemisphere due to the greater amount of land compared to water. As a result, the northern hemisphere tends to be warmer, and the thermal equator (also known as the Intertropical Convergence Zone or ITCZ) usually lies north of the geographical equator.
- When isotherms pass through areas with warm ocean currents, they tend to shift poleward, as seen with the

North Atlantic Drift and Gulf Stream combined with westerlies in the North Atlantic, and the Kurishino Current and North Pacific current combined with westerlies in the North Pacific.

- Moreover, mountains can also influence the horizontal distribution of temperature. For example, the Rocky Mountains and the Andes act as barriers, preventing oceanic influences from extending further inland into North and South America.

Inter Tropical Convergence Zone

The Inter-Tropical Convergence Zone (ITCZ) is an extensive region of low pressure located near the equator, where the northeast and southeast trade winds come together. This area of convergence generally aligns with the equator but shifts north or south depending on the sun's apparent movement.



ITCZ

Seasonal Temperature Distribution

- The distribution of global temperatures can be better understood by examining the temperature patterns in January and July. Temperature distribution is typically illustrated on maps using isotherms, which are lines that connect places with the same temperature. Generally, isotherms tend to run parallel to lines of latitude, demonstrating the influence of latitude on temperature. This pattern, however, is more noticeable in July than in January, particularly in the northern hemisphere.
- In the northern hemisphere, there is a larger land surface area compared to the southern hemisphere. As a result, the impacts of landmasses and ocean currents on temperature distribution are more evident in this region. Overall, studying temperature distribution during these two months can provide valuable insights into the global distribution of temperatures and the factors that influence it.

Seasonal Temperature Distribution – January

- During January, it is winter in the northern hemisphere and summer in the southern hemisphere.
- **The western margins of continents are warmer than their eastern counterparts since the Westerlies are able to carry high temperature into the landmasses.**
- The temperature gradient is close to the eastern margins of continents. The isotherms exhibit a more regular behavior in the southern hemisphere.

Northern Hemisphere

- In the Northern Hemisphere, the isotherms - lines that connect points of equal temperature - show a deviation to the north over the ocean and to the south over the continent. This pattern is particularly noticeable in the North Atlantic Ocean.
- This deviation can be attributed to the presence of warm ocean currents, such as the Gulf Stream and the North Atlantic Drift. These currents make the North Atlantic Ocean warmer, causing the isotherms to shift poleward. This indicates that the oceans are able to carry higher temperatures towards the poles.
- Conversely, an equatorward bend of the isotherms over the northern continents demonstrates that these landmasses are significantly cooler. This is due to the ability of cold polar winds to penetrate southwards, even into the interiors of continents. This effect is especially pronounced in the Siberian plain.
- The lowest temperatures in the Northern Hemisphere are recorded in northern Siberia and Greenland, highlighting the impact of these cooling effects on continental landmasses.

Southern Hemisphere

- The effect of the ocean is well pronounced in the southern hemisphere. Here the isotherms are more or less parallel to the latitudes and the variation in temperature is more gradual than in the northern hemisphere.
- The high-temperature belt runs in the southern hemisphere, somewhere along 30°S latitude.
- The thermal equator lies to the south of the geographical equator (because the Intertropical Convergence Zone or

ITCZ has shifted southwards with the apparent southward movement of the sun).

Seasonal Temperature Distribution – July

- During July, it is summer in the northern hemisphere and winter in the southern hemisphere. The isothermal behavior is the opposite of what it is in January.
- In July the isotherms generally run parallel to the latitudes. The equatorial oceans record warmer temperatures, more than 27°C. Over the land more than 30°C is noticed in the subtropical continental region of Asia, along the 30° N latitude.

Northern Hemisphere

- The highest temperature range, exceeding 60°C, can be found in the northeastern part of the Eurasian continent, which is due to the effect of continentality. On the other hand, the smallest temperature range of 3°C occurs between 20° S and 15° N latitudes.
- In the northern continents, isotherms (lines of equal temperature) bend towards the poles, indicating that these landmasses experience high temperatures and the warm tropical winds can penetrate far into the northern regions. In contrast, isotherms over the northern oceans shift towards the equator, suggesting that these oceanic areas are cooler, and they help moderate the temperatures in the tropical regions. The coldest temperatures are typically found over Greenland.
- The belt with the highest temperatures goes through northern Africa, West Asia, northwestern India, and the southeastern United States. The temperature gradient in the northern hemisphere is irregular, with isotherms following a zig-zag pattern.

Southern Hemisphere

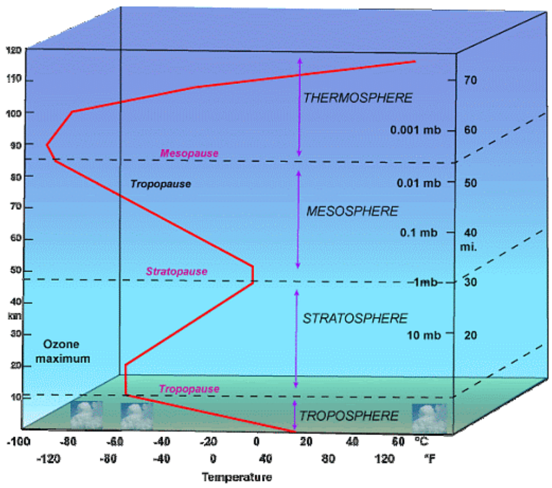
- In the Southern Hemisphere, the impact of the ocean on temperature is quite significant. In this region, the lines of equal temperature, or isotherms, tend to run parallel to lines of latitude, resulting in a more gradual change in temperature compared to the Northern Hemisphere.
- A zone of high temperatures can be found around the 30°S latitude in the Southern Hemisphere. Additionally, the thermal equator, or the line marking the area with the highest average temperatures, is located south of the geographical equator. This is due to the southward shift of the Intertropical Convergence Zone (ITCZ), which occurs as the sun appears to move southward.

Vertical Distribution of Temperature

- The normal, lapse rate is uniform at a given level at all altitudes within the troposphere.
- At the Tropopause, the lapse rate stops at zero i.e. there is no change in temperature there.
- In the lower stratosphere, the lapse rate remains constant for some height, while higher temperatures exist over the poles because this layer is closer to earth at the poles.

Temperature Anomaly

- The difference between the mean temperature of a place and the mean temperature of its parallel (latitude) is called the temperature anomaly or thermal anomaly.
- The largest anomalies occur in the northern hemisphere and the smallest in the southern hemisphere.

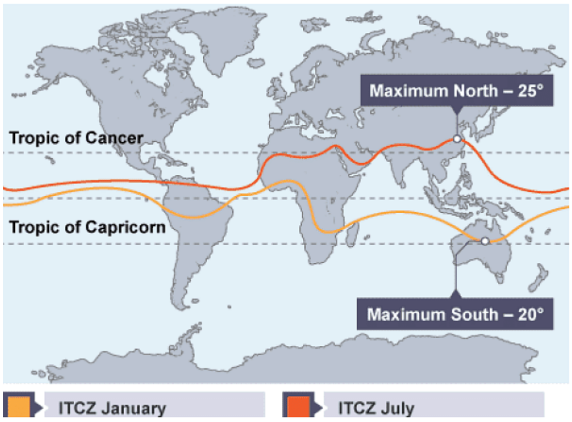


Mean Thermal Equator

- The thermal equator refers to a global isotherm representing the highest mean annual temperature at each longitude around the planet. It is important to note that the thermal equator does not align exactly with the geographical equator. While the highest absolute temperatures can be found in the Tropics, the highest mean annual temperatures are generally recorded at the equator. However, local temperatures can be significantly impacted by geographical factors such as mountain ranges and ocean currents, leading to deviations in the location of the thermal equator from that of the geographic Equator.
- The Earth's distance from the Sun varies throughout the year, with its closest approach (perihelion) occurring in early January and its farthest point (aphelion) in early

July. During the respective hemispheres' winter seasons, the angle at which sunlight reaches the tropics is relatively low, causing the average annual temperature in these regions to be lower than that observed near the equator. This is due to the minimal change in the angle of sunlight at the equator.

- Throughout the year, the thermal equator shifts north and south, following the movement of the Sun's vertical rays. However, on average, the position of the thermal equator is around 5° N latitude. This is because the highest mean annual temperature moves more significantly northward during the summer solstice than it does southward during the winter solstice.



What is the primary reason for higher temperatures in the Torrid Zone compared to the Temperate and Frigid Zones? **A.** Higher altitude **B.** Proximity to water bodies **C.** Angle at which sunlight strikes the Earth's surface **D.** Influence of ocean currents

Conclusion

The Earth's temperature distribution is influenced by a variety of factors, including latitude, altitude, proximity to water bodies, and ocean currents. The planet is divided into three primary heat zones, which are the Torrid, Temperate, and Frigid Zones. The transparency of the atmosphere, Earth's distance from the Sun, and the type of land surface also play significant roles in the heating and cooling of the atmosphere. Isotherms are used to illustrate temperature distribution and reveal general patterns, such as the thermal equator, which varies seasonally and deviates from the geographical equator. Understanding these factors and their impact on temperature distribution is crucial for studying climate changes and global weather conditions.

What are the three primary heat zones of the Earth?

The three primary heat zones of the Earth are the Torrid Zone (Tropical Zone), the Temperate Zone, and the Frigid Zone. These zones are determined by their proximity to the Equator and are characterized by their distinct temperature ranges and climate conditions.

What factors influence temperature patterns on the globe?

Several factors influence temperature patterns on the globe, including latitude, altitude, proximity to oceans and seas, local wind effects, continentality (distance from large water bodies), and slope aspect (the direction a slope faces).

What is the significance of ocean currents in regulating temperatures?

Ocean currents play a crucial role in regulating temperatures in coastal regions by transporting warm and cold water from different parts of the world. Coastal regions influenced by warm currents will experience milder temperatures during winter months, while those influenced by cold currents can experience cooler temperatures.

What is an isotherm, and what are its general characteristics?

An isotherm is an imaginary line joining places with equal temperatures. Isotherms generally follow the lines of latitude, running parallel to each other. However, they can bend at the boundaries between oceans and continents due to the different heating properties of land and water. When isotherms are closely spaced, it indicates a rapid temperature change, while widely spaced isotherms suggest a slow temperature change.

How does the distribution of temperature vary during different seasons?

During different seasons, the distribution of temperature varies as a result of factors such as the angle of sunlight, proximity to oceans and seas, and the influence of landmasses and ocean currents. For example, during January, the temperature gradient is close to the eastern margins of continents, while in July, the isotherms generally run parallel to the latitudes. These variations in temperature distribution help us understand global temperature patterns throughout the year.

1. What are temperature belts of the world?

Ans. Temperature belts of the world refer to the regions on Earth that are characterized by distinct temperature patterns. These belts are primarily determined by the latitude and are divided into three main categories: the low-latitude or tropical belt, the mid-latitude or temperate belt, and the high-latitude or polar belt.

2. What is the transparency of the atmosphere?

Ans. The transparency of the atmosphere refers to the ability of the Earth's atmosphere to allow the passage of sunlight through it. It is influenced by various factors such as the presence of gases, particles, and aerosols in the atmosphere. The transparency of the atmosphere plays a crucial role in determining the amount of solar radiation reaching the Earth's surface.

3. What is the Inter Tropical Convergence Zone (ITCZ)?

Ans. The Inter Tropical Convergence Zone (ITCZ) is a belt of low pressure and atmospheric convergence located near the equator. It is characterized by the meeting of trade winds from both the Northern and Southern Hemispheres. The ITCZ experiences high temperature and humidity, resulting in the formation of abundant clouds and heavy rainfall. It is also associated with the occurrence of tropical cyclones.

4. What is the Mean Thermal Equator?

Ans. The Mean Thermal Equator is an imaginary line that represents the average position of the highest surface temperature on Earth throughout the year. It is influenced by factors such as solar radiation, land-ocean distribution, and atmospheric circulation patterns. The Mean Thermal Equator tends to shift northward during the Northern Hemisphere summer and southward during the Southern Hemisphere summer.

5. Why are FAQs related to temperature and pressure belts important for the UPSC exam?

Ans. Temperature and pressure belts are essential topics within the field of geography and climatology, which are relevant for the UPSC exam. Understanding these concepts helps in comprehending global climate patterns, weather phenomena, and their impact on human societies. By studying frequently asked questions on temperature and pressure belts, UPSC candidates can enhance their knowledge and prepare effectively for the exam.

Atmospheric Circulation

Atmosphere

The atmosphere, a layer of gases surrounding Earth, serves as a protective barrier between our planet and outer space. It is a vital component of the biosphere, as it enables life to exist on Earth's surface. The atmosphere is comprised of colorless, odorless, tasteless, and formless gases that are so thoroughly mixed that they behave as a single gas.

- The gases present in the atmosphere are not direct remnants from Earth's early formation. Instead, they have been produced over time through volcanic eruptions, hot springs, chemical breakdowns of solid materials, and redistribution from the biosphere.
- The atmosphere plays a crucial role in supporting life on Earth. It contains essential gases such as oxygen for humans and animals, and carbon dioxide for plants. The atmosphere also shields Earth from harmful solar radiation and functions as a greenhouse by allowing short-wave radiation from the Sun to enter while trapping long-wave terrestrial radiation emitted from Earth's surface.
- Life forms require specific temperature ranges and solar radiation frequencies to carry out their biological processes. The atmosphere absorbs certain frequencies of solar radiation and allows others to pass through, effectively regulating the solar radiation that reaches Earth's surface. Furthermore, the atmosphere helps maintain temperature stability on Earth's surface, preventing extreme temperature fluctuations between day and night.
- The atmosphere also serves as a protective barrier against extraterrestrial objects, such as meteors, which burn up as they pass through the atmosphere (specifically, the mesosphere) due to friction.

Composition of the atmosphere

The atmosphere is composed of

- Gases
- Vapour
- Particulates

The atmosphere is a mixture of many gases. In addition, it contains huge numbers of solid and liquid particles, collectively called aerosols.

Gases in the Atmosphere

- The atmosphere is primarily composed of nitrogen and oxygen, which together account for nearly 99% of clean, dry air. The remaining 1% consists of mostly inert gases. Oxygen, though it only makes up 21% of the atmosphere, is crucial for life on Earth. It is inhaled by living organisms and forms important compounds, such as oxides, through its ability to combine with other elements. Oxygen is also essential for combustion.
- Nitrogen is the most abundant gas in the atmosphere, comprising 78% of its total volume. Although relatively inert, nitrogen is a key component of all organic compounds. Its primary function is to regulate combustion by diluting oxygen, and it also plays a role in various oxidation processes.
- Carbon dioxide is another important gas, despite constituting only about 0.038% of the dry atmosphere. It is a byproduct of combustion and is absorbed by green plants through photosynthesis for food production and other biological processes. Carbon dioxide has significant climatic implications due to its efficient heat-absorbing properties. The increasing burning of fossil fuels has raised the percentage of carbon dioxide in the atmosphere, which could result in higher temperatures at lower atmospheric levels and lead to significant climate changes. Carbon dioxide and water vapor are primarily found up to 90 km from the Earth's surface.
- Argon is another notable gas, making up approximately 0.93% of the atmosphere. Ozone (O_3) is a type of oxygen molecule consisting of three atoms instead of two and constitutes less than 0.00006% of the atmospheric volume. Ozone is unevenly distributed and primarily concentrated between 20 km and 25 km altitude. It is formed at higher altitudes and transported downwards, playing a critical role in blocking harmful ultraviolet radiation from the sun.

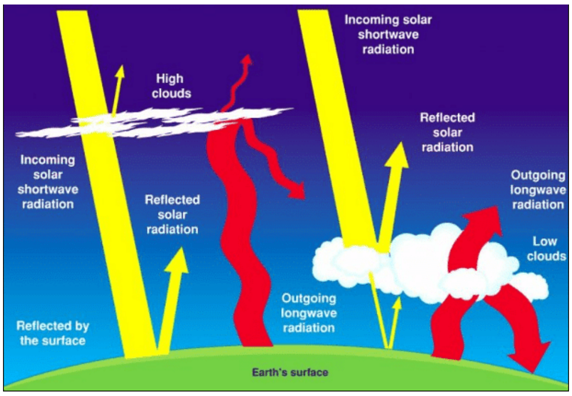
- Other trace gases in the atmosphere include neon, helium, hydrogen, xenon, krypton, and methane, which are present in negligible quantities.

Water Vapour

Water vapor is a key component of the Earth's atmosphere, making up anywhere from 0 to 5% of its total volume. This vapor is primarily obtained through the evaporation of water from various sources, such as oceans, seas, lakes, rivers, ponds, and even vegetation and soil.

- The concentration of water vapor in the atmosphere is highly dependent on temperature, which is why it decreases as one moves from the equator towards the poles. For example, in tropical regions near the equator, the surface air contains about 2.6% water vapor, whereas at 50-degree and 70-degree latitudes, the concentrations are 0.9% and 0.2%, respectively.
- Additionally, the amount of water vapor in the atmosphere tends to decrease with altitude. In fact, over 90% of the total atmospheric water vapor is found within the first 5 km above the Earth's surface.
- The presence of water vapor in the atmosphere contributes to various forms of condensation and precipitation, such as clouds, fog, dew, rain, frost, hail, ice, and snowfall. These phenomena occur when the moisture content in the atmosphere reaches a certain level and temperature conditions are favorable.
- An interesting property of water vapor is its transparency to incoming shortwave solar radiation. This means that the sun's electromagnetic waves can pass through the atmosphere and reach the Earth's surface with little interference from water vapor. However, water vapor is less transparent to outgoing longwave terrestrial radiation, which is emitted by the Earth's surface as it absorbs solar energy. As a result, water vapor plays a crucial role in warming the Earth's surface and lower atmosphere by absorbing and retaining this terrestrial radiation.

In summary, water vapor is an essential component of the Earth's atmosphere, with its concentration varying depending on factors such as temperature and location. It plays a vital role in the formation of various weather phenomena and contributes to the Earth's overall climate by regulating the absorption and retention of solar and terrestrial radiation.



Water Vapour & Solar Radiation

Atmospheric Particulate Matter

- The atmosphere contains solid particles such as sand (from weathered rocks and volcanic ash), pollen grains, tiny organisms, soot, ocean salts, and even fragments of meteors that have burned up in the atmosphere. These particulates play a crucial role in absorbing, reflecting, and scattering solar radiation, which creates the beautiful red and orange hues seen during sunrise and sunset.
- The blue color of the sky is a result of the selective scattering of solar radiation by dust particles. Additionally, salt particles serve as hygroscopic nuclei, which aid in the formation of water droplets, clouds, and different types of condensation and precipitation.
- A hygroscopic nucleus is a microscopic particle, such as sulfur dioxide, salt, dust, or smoke, that serves as a platform for water vapor to condense into droplets.

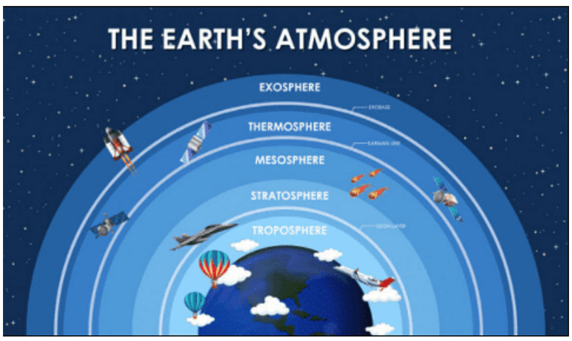
Why is the ozone layer important for life on Earth? **A.** It absorbs and retains terrestrial radiation **B.** It reflects radio waves for long-distance communication **C.** It provides oxygen for respiration **D.** It protects living organisms from harmful ultraviolet radiation

Structure of the Atmosphere

The atmosphere is composed of various layers that can be categorized based on their composition, density, pressure, and temperature differences.

Composition-wise, the atmosphere can be broadly divided into two main layers: the homosphere and the heterosphere.

- **The homosphere** consists of three regions: the Troposphere, the Stratosphere, and the Mesosphere. While the air composition remains consistent throughout these regions, the concentration of air significantly diminishes with an increase in altitude.
- **The Troposphere** is the lowest layer of the atmosphere and is responsible for Earth's weather as it contains most weather conditions. The temperature decreases as altitude increases in this region.
- The Stratosphere is situated in the middle of the homosphere, while the Mesosphere is its uppermost layer.
- **The heterosphere**, on the other hand, contains two regions: the Thermosphere and the Exosphere. These regions are considered part of outer space and have unevenly mixed gases. The Ionosphere overlaps both the Mesosphere and the Thermosphere.
- **The Thermosphere** is the lower region of the heterosphere, while the Exosphere is its uppermost region.
- **The homosphere** extends from Earth's surface up to an altitude of 80 km. Although the atmosphere's density rapidly diminishes with an increase in altitude, the gas composition remains uniform within the homosphere. Exceptions to this uniformity include the concentration of ozone (O3) in the stratosphere from roughly 19-50 km and the variation of water vapor and dust particles in the lower atmosphere. This uniform composition was achieved around 600 million years ago.
- The heterosphere begins at an altitude of over 80 km and extends up to 10,000 km. However, for scientific purposes, the atmosphere's upper limit is considered to be 480 km, as Earth's gravitational pull becomes negligible beyond this point. The atmosphere above this limit is referred to as the exosphere and contains individual atoms of lightweight gases such as hydrogen and helium.

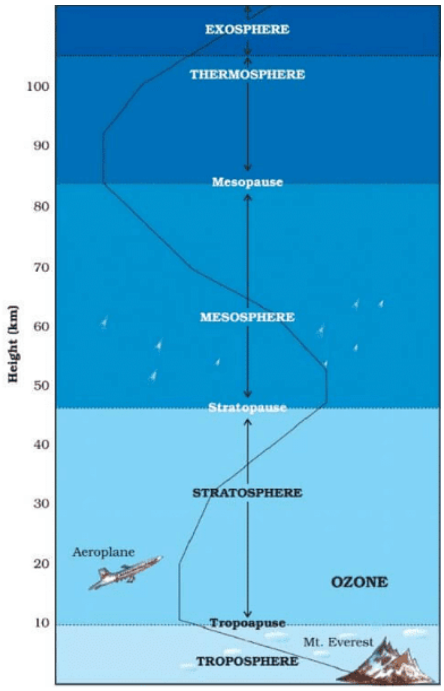


Earth Atmosphere

Based on Change in temperature

The atmosphere is composed of five distinct layers, each characterized by variations in temperature and density. These layers include:

- **Troposphere:** This is the lowest layer of the atmosphere, where weather occurs and temperature decreases with altitude.
- **Stratosphere:** Above the troposphere, this layer features a temperature increase with altitude and contains the ozone layer.
- **Mesosphere:** In this layer, temperatures decrease with altitude, and it is the region where meteors burn up upon entering Earth's atmosphere.
- **Thermosphere (Ionosphere):** The temperature rises significantly in this layer due to solar radiation absorption. It is also known as the Ionosphere because it contains charged particles that enable radio wave communication.
- **Exosphere:** This is the outermost layer of the atmosphere, where temperatures remain constant with altitude, and the density of air particles is extremely low.



Structure of the Atmosphere

Troposphere:

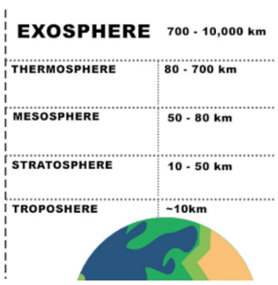
- The troposphere is the lowest layer of Earth's atmosphere, extending up to 18 km at the equator, 13 km at mid-latitudes, and approximately 8 km at the poles.

This layer contains around 90% of the atmosphere's total mass and is the region where all weather phenomena occur, such as the presence of water vapor, dust particles, and clouds.

- In the troposphere, temperature decreases as altitude increases. The average rate of this temperature decrease is called the normal lapse rate, which is roughly 6.4 degrees Celsius per kilometer. However, this rate is not constant everywhere, and the specific rate of temperature decrease in a particular location is referred to as the local lapse rate. The minimum temperature reached in the troposphere is around -57 degrees Celsius.
- The tropopause is the upper boundary of the troposphere, separating it from the stratosphere above. This boundary is characterized by a constant temperature, acting as a transitional zone between the two atmospheric layers.

Stratosphere

- The stratosphere is a layer of Earth's atmosphere situated above the troposphere and extending up to 50 kilometers across the globe. In this region, temperatures rise as altitude increases, ranging from -57 to 0 degrees Celsius.
- A key feature of the stratosphere is the presence of the ozonosphere, which consists of highly reactive ozone molecules composed of three oxygen atoms. The ozone layer plays a critical role in absorbing high-frequency ultraviolet (UV) radiation, which leads to an increase in temperature within the stratosphere.
- The absorption of energy by the ozone molecules causes chemical reactions that result in the formation of ozone gas. By absorbing harmful UV rays, the ozone layer serves as a protective barrier for living organisms, including plants, animals, and humans, shielding them from the detrimental effects of these ultraviolet radiations.



Layers of Atmosphere

Mesosphere

- The mesosphere is a layer of Earth's atmosphere that stretches from 50 to 80 kilometers above the surface. Within this layer, the temperature decreases, reaching an average low of -90°C, although it can vary.
- This layer is part of a homogenous region that extends up to the mesosphere. At the upper boundary of the mesosphere, there is a layer of charged particles, also known as ions, that extends into the next atmospheric layer. This ion layer plays a significant role in reflecting radio waves, which is crucial for telecommunications.

Thermosphere

- The thermosphere is a region that spans from 80 km to 480 km above the Earth's surface. Within this region, the ionosphere functions due to the presence of charged particles. As the gas molecules in this layer absorb shortwave solar radiation, the temperature dramatically increases, possibly reaching up to 1200°C.
- However, the thermosphere does not feel as hot as one might expect, given its high temperatures. This is because the air density in this layer is extremely low, resulting in a reduced ability to transfer energy. Consequently, the sensation of heat is not experienced as it would be in denser regions.

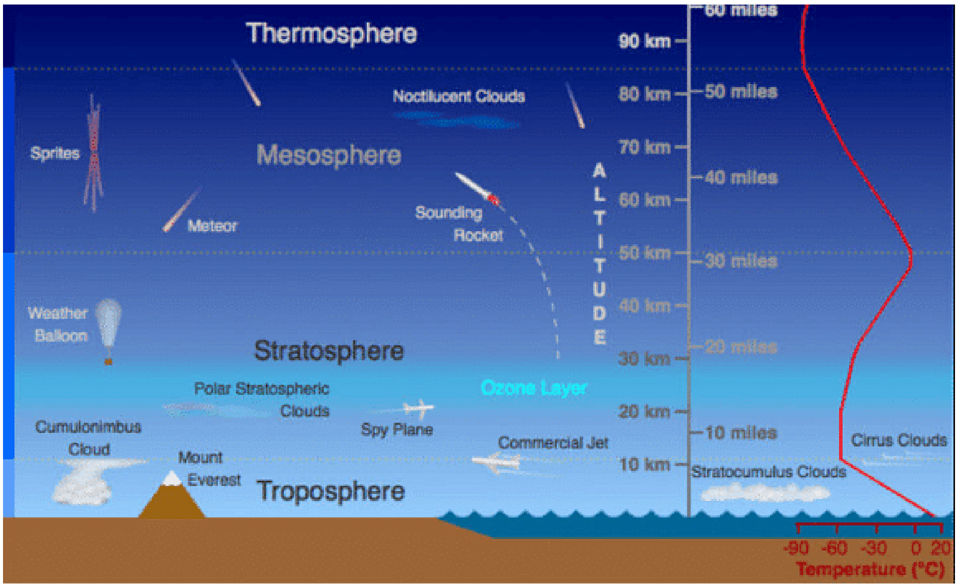
Ionosphere

- The ionosphere is a region of the Earth's atmosphere, extending from the upper mesosphere to the lower thermosphere, approximately 60 to 400 kilometers (40 to 250 miles) above the Earth's surface. It contains charged particles, known as ions, which are created by the absorption of cosmic rays, gamma rays, X-rays, and ultraviolet rays with shorter wavelengths.
- This layer of the atmosphere is crucial for long-distance communication, as it reflects radio waves back to Earth, enabling signals to travel across vast distances. The ionosphere is also responsible for the beautiful auroral displays, such as the "northern lights," which occur when charged particles from the Sun are trapped by Earth's magnetic field near the poles. These particles "excite" nitrogen molecules and oxygen atoms in the ionosphere, causing them to emit light in a similar fashion to a neon light bulb.
- As we move higher within the ionosphere, atomic oxygen becomes more prevalent at altitudes above 480 kilometers (298 miles). Beyond this point, helium

becomes more common, followed by a predominance of hydrogen atoms. One notable phenomenon that occurs within the ionosphere is the heating of incoming space vehicles and meteorites due to friction with the charged particles.

Exosphere

- The exosphere is the highest layer of the atmosphere, where gases are extremely sparse due to the minimal influence of gravitational forces.
- As a result, the air density in this region is significantly lower compared to other atmospheric layers.

- 

What role does water vapor play in the Earth's atmosphere?

A. It contributes to the formation of weather phenomena and regulates the absorption and retention of solar and terrestrial radiation

B. It aids in reflecting radio waves for long-distance communication

C. It maintains the uniform gas composition in the homosphere

D. It serves as a platform for water vapor to condense into droplets

Conclusion

Earth's atmosphere is a complex and essential component of the biosphere, providing a protective barrier and supporting life on the planet. Composed of various gases, water vapor, and particulate matter, the atmosphere is divided into distinct layers based on composition, temperature, and density. Each layer plays a crucial role in maintaining temperature stability, shielding Earth from harmful radiation, and enabling various weather phenomena and long-distance communication. Understanding the structure and functions of the atmosphere is vital for monitoring and addressing climate change and other environmental challenges.

What are the primary gases that make up Earth's atmosphere?

The Earth's atmosphere is primarily composed of nitrogen (78%) and oxygen (21%). The remaining 1% consists of other gases like argon, carbon dioxide, and trace amounts of other gases such as neon, helium, hydrogen, xenon, krypton, and methane.

What is the importance of the ozone layer in Earth's atmosphere?

The ozone layer, located within the stratosphere, is essential because it absorbs high-frequency ultraviolet (UV) radiation from the Sun. By doing so, it protects living organisms on Earth, including plants, animals, and humans, from the harmful effects of these UV rays.

How does the atmosphere contribute to the Earth's overall climate?

The atmosphere, particularly water vapor, plays a crucial role in regulating the Earth's climate by absorbing, reflecting, and scattering solar radiation. It also helps maintain temperature stability on Earth's surface by allowing short-wave radiation from the Sun to enter while trapping long-wave terrestrial radiation emitted from Earth's surface.

How does the ionosphere enable long-distance communication?

The ionosphere contains charged particles, or ions, which are created by the absorption of cosmic rays, gamma rays, X-rays, and ultraviolet rays with shorter wavelengths. These charged particles reflect radio waves back to Earth, enabling signals to travel across vast distances and facilitating long-distance communication.

What is the difference between the homosphere and the heterosphere in Earth's atmosphere?

The homosphere is the region of the atmosphere that extends from Earth's surface up to an altitude of 80 km. In this region, the gas composition remains uniform, with some exceptions such as the concentration of ozone in the stratosphere. The heterosphere begins at an altitude of over 80 km and extends up to 10,000 km, where gases are unevenly mixed due to the minimal influence of gravitational forces.

1. What is atmospheric particulate matter?

Ans. Atmospheric particulate matter refers to tiny solid or liquid particles suspended in the air. These particles can originate from natural sources such as dust, pollen, and volcanic eruptions, as well as human activities such as industrial emissions and vehicle exhaust. They have various sizes and compositions, ranging from large dust particles to smaller aerosols.

2. How does atmospheric particulate matter affect human health?

Ans. Atmospheric particulate matter can have adverse effects on human health. When inhaled, these particles can penetrate deep into the respiratory system and cause respiratory issues such as asthma, bronchitis, and other respiratory diseases. Fine particles, known as PM2.5, are of particular concern as they can enter the bloodstream and affect other organs, leading to cardiovascular problems and even premature death.

3. What is the structure of the atmosphere?

Ans. The atmosphere is divided into several layers based on their characteristics. The lowest layer is the troposphere, which extends from the Earth's surface up to an average height of 12 kilometers. Above the troposphere, we have the stratosphere, mesosphere, thermosphere, and exosphere. Each layer has its unique properties, such as temperature changes and the presence of specific gases.

4. How does atmospheric circulation occur?

Ans. Atmospheric circulation refers to the large-scale movement of air around the Earth. It is driven by differences in temperature and pressure. When air near the equator gets heated, it rises, creating a low-pressure zone. This rising air then moves towards the poles, cools down, and descends at higher latitudes, creating high-pressure zones. This circulation pattern, known as Hadley cells, Ferrel cells, and Polar cells, creates prevailing winds and weather patterns.

5. What is the significance of understanding atmospheric circulation?

Ans. Understanding atmospheric circulation is essential as it helps us predict and understand weather patterns and climate. It plays a vital role in determining regional climates, such as the monsoon system. Studying atmospheric circulation also helps us comprehend the distribution of pollutants and their transport across different regions. Additionally, it aids in understanding the global energy balance and the dynamics of Earth's climate system.

Heat Budget of The Earth

Introduction

The Earth's heat budget refers to the equilibrium between the incoming solar energy, known as solar insolation, and the outgoing heat emitted by the planet, called terrestrial radiation. This balance is crucial for maintaining the Earth's average annual temperature at around 15 degrees Celsius (59 degrees Fahrenheit). In simpler terms, the heat budget ensures that the Earth does not become too hot or too cold by regulating the amount of solar energy it receives and the heat it releases back into space.

Heat Budget of the Earth and Atmosphere

- The Earth's heat budget refers to the balance between the total solar radiation that reaches the Earth's surface and the heat energy that is emitted back into the atmosphere. This solar radiation, known as global radiation, consists of both direct shortwave radiation from the Sun and diffuse radiation that has been scattered by the atmosphere.
- When this solar radiation reaches the Earth's surface, it is transformed into heat energy, which in turn warms the planet's outer surface. As a result, the Earth also emits energy back into the atmosphere in the form of long-wave radiation. This process involves two main types of radiation: incoming shortwave solar radiation from the Sun toward the Earth, and outgoing longwave terrestrial radiation from the Earth back into the atmosphere.
- The balance of these two forms of radiation is crucial for maintaining the Earth's overall temperature and climate.

What is the Earth's albedo? A. The amount of solar radiation absorbed by the Earth **B.** The percentage of incoming solar radiation reflected back into space **C.** The Earth's average annual temperature **D.** The balance between incoming solar radiation and outgoing terrestrial radiation

How it is calculated?

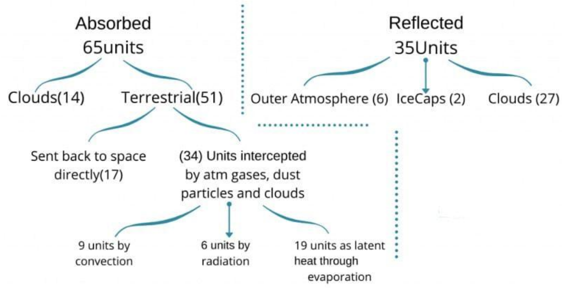
Suppose incoming solar insolation is = 100 units Amount lost through scattering and reflection.

a) Through Clouds- 27units

b) By dust particles – 6units

c) By Ice Caps and Glaciers- 2units

Total 35 units are reflected back into space. (known as albedo of the earth) Now, the units received by earth and its atmosphere = 100 – 35 = 65units.



Heat budget of the Earth

The Earth's heat budget consists of the balance between the incoming solar radiation and the outgoing terrestrial radiation. A total of 51 units of solar insolation are received by the Earth, which can be divided into two categories:

- Direct Radiation: 34 units
- Diffused Daylight: 17 units

Together, this amounts to 51 units of solar radiation.

The heat budget of the atmosphere involves the absorption of solar radiation by atmospheric gases in different vertical zones, which accounts for 14 units. Combining this with the initial 51 units, the total solar insolation received by the Earth and its atmosphere amounts to 65 units. Out of the 51 units of solar radiation received directly by the Earth, 17 units are re-radiated back into outer space, while the remaining 34 units are absorbed by the atmosphere in the form of outgoing terrestrial radiation. This results in a total of 48 units (14 + 34 = 48) of atmospheric heat.

- **Albedo** refers to the measure of how much light that strikes a surface is reflected back without being absorbed. It is represented as a reflection coefficient with a value of less than one. As solar radiation passes through the atmosphere, a portion of it is reflected, scattered, and absorbed. The amount of radiation that is reflected is known as the Earth's albedo.
- The effect of albedo can lead to higher average temperatures in highly developed areas, such as urban cities, compared to surrounding suburban or rural areas.

This phenomenon is known as the Urban Heat Island Effect. Factors contributing to this effect include a lack of vegetation, higher population densities, and the presence of dark surfaces, such as asphalt roads and brick buildings, which absorb more heat.

What is the Urban Heat Island Effect?

A. The effect of the Earth's albedo on global temperatures
B. The balance between incoming solar radiation and outgoing terrestrial radiation
C. The phenomenon of higher average temperatures in urban areas compared to surrounding suburban or rural areas
D. The absorption of solar radiation by the Earth's atmosphere

Conclusion

The Earth's heat budget is a critical equilibrium between incoming solar radiation and outgoing terrestrial radiation, which maintains the planet's average temperature and climate. The balance of these radiations is influenced by various factors such as albedo, which plays a significant role in regulating the Earth's temperature. Understanding the heat budget and its components is essential for addressing climate change and preserving our planet's delicate balance.

What is the Earth's heat budget?

The Earth's heat budget refers to the equilibrium between the incoming solar energy (solar insolation) and the outgoing heat emitted by the planet (terrestrial radiation). This balance is essential for maintaining the Earth's average annual temperature and overall climate.

What is solar insolation?

Solar insolation refers to the total amount of solar radiation that reaches the Earth's surface. It consists of direct shortwave radiation from the Sun and diffuse radiation that has been scattered by the atmosphere.

What is terrestrial radiation?

Terrestrial radiation refers to the long-wave radiation emitted by the Earth's surface back into the atmosphere. This process helps maintain the Earth's heat budget by balancing the incoming solar radiation with the outgoing heat emitted by the planet.

What is albedo, and how does it affect the Earth's heat budget?

Albedo refers to the measure of how much light that strikes a surface is reflected back without being absorbed. The Earth's albedo is the portion of solar radiation that is reflected, scattered, and absorbed as it passes through the atmosphere. Albedo plays a crucial role in maintaining the Earth's heat budget by regulating the amount of solar radiation that reaches the Earth's surface.

What is the Urban Heat Island Effect?

The Urban Heat Island Effect is a phenomenon where highly developed areas, such as urban cities, have higher average temperatures compared to surrounding suburban or rural areas. This effect is attributed to factors such as a lack of vegetation, higher population densities, and the presence of dark surfaces like asphalt roads and brick buildings that absorb more heat.

1. What is the heat budget of the Earth?

Ans. The heat budget of the Earth refers to the balance between the incoming and outgoing energy in the Earth's atmosphere. It represents the flow of energy through various processes such as radiation, conduction, and convection.

2. How is the heat budget of the Earth maintained?

Ans. The heat budget of the Earth is maintained through a combination of different processes. The Sun provides the primary source of energy, with the incoming solar radiation being absorbed by the Earth's surface. This absorbed energy is then re-radiated back into the atmosphere, where it is either absorbed or reflected by various atmospheric components, such as clouds, gases, and particles. Additionally, the heat budget is also regulated by ocean currents, winds, and the redistribution of heat through atmospheric and oceanic circulation.

3. What role does greenhouse effect play in the heat budget of the Earth?

Ans. The greenhouse effect plays a crucial role in the heat budget of the Earth. Certain gases in the Earth's atmosphere, such as carbon dioxide, methane, and water vapor, act as greenhouse gases. They absorb and re-radiate the outgoing infrared radiation, trapping heat in the atmosphere and maintaining a relatively stable temperature on Earth. Without the greenhouse effect, the Earth's average temperature would be much colder, making it unsuitable for most forms of life.

4. How does the heat budget of the Earth impact climate change?

Ans. The heat budget of the Earth is closely linked to climate change. Human activities, such as the burning of fossil fuels and deforestation, have significantly increased the concentration of greenhouse gases in the atmosphere. This has enhanced the greenhouse effect, leading to global warming and climate change. The imbalance in the heat budget caused by the increased trapping of heat by greenhouse gases contributes to the rising temperatures, melting of ice caps, changes in weather patterns, and other climate-related impacts.

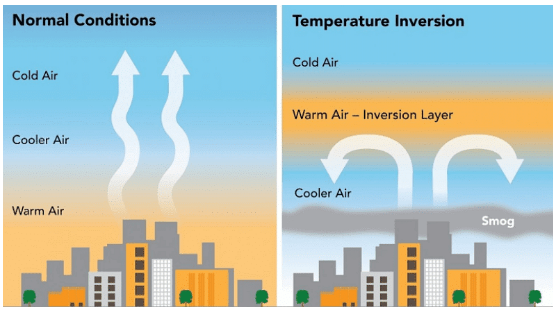
5. How can we measure and monitor the heat budget of the Earth?

Ans. The heat budget of the Earth can be measured and monitored through various scientific methods. Satellites equipped with instruments like radiometers and spectrometers can measure the incoming solar radiation and the outgoing infrared radiation from Earth. Ground-based weather stations, buoys, and oceanic sensors can also collect data on temperature, humidity, wind patterns, and ocean currents. These measurements are crucial for understanding the Earth's energy balance and monitoring changes over time, helping scientists make predictions and assess the impacts of climate change.

Atmospheric Stability & Instability

Typically, the temperature in the troposphere decreases as altitude increases, with a normal lapse rate of 1 degree for every 165 meters. This is the usual pattern of temperature change in the atmosphere. However, in some instances, this pattern can reverse, causing the temperature to increase with height instead of decreasing. This phenomenon is known as temperature inversion.

The environmental lapse rate, or the rate at which temperature changes with altitude, can vary depending on location and time, particularly in the lowest few hundred meters of the troposphere. On average, the temperature change is approximately 6.5°C per 1000 meters (or 3.6°F per 1000 feet). This average rate is referred to as the average lapse rate or the average vertical temperature gradient within the troposphere.



Temperature Inversion

The average lapse rate indicates that for every 1000 meters increase in altitude, the temperature typically decreases by 6.5°C. Conversely, if we measure the temperature 1000 meters below a previous point, it will be about 6.5°C warmer.

A temperature inversion, also known as thermal inversion, occurs when the usual pattern of temperature decrease with increasing altitude is reversed. In other words, instead of the temperature dropping as we move higher up in the

troposphere, it actually increases. This results in a layer of warm air settled above a layer of colder air. Temperature inversion is also referred to as a negative lapse rate because it goes against the expected temperature behavior in the atmosphere.

There are several factors that can cause temperature inversion, such as stable atmospheric conditions or the horizontal or vertical movement of air. Although temperature inversions are generally short-lived, they are fairly common occurrences in meteorology.

Effects of Temperature Inversion

Temperature inversion can have several negative effects on society and the economy in regions where it occurs. Some of the primary consequences of temperature inversion are:

- **Formation of fog:** Temperature inversion can lead to the development of fog, which is essentially a cloud in contact with the ground. Visibility is typically reduced to less than 1 km in such conditions. In urban areas, fog can mix with smoke to create smog, which is a health hazard. Fog can harm crops, while smog can cause respiratory issues like asthma and bronchitis. In 1952, around 4,000 people died from smog in London. Breathing problems are common during the winter season in cities like Delhi and other major cities in northern India.
- **Increased road accidents:** Visibility can be significantly reduced during temperature inversion due to the accumulation of dust and smoke particles. As a result, there is an increased frequency of road, rail, and air accidents. Trains and flights are often delayed due to poor visibility.
- **Crop damage:** Winter crops, such as wheat, barley, mustard, vegetables, chilies, and potatoes, can be severely affected by temperature inversion. In the northern plains of India, sugarcane crops can develop a red rot disease, which reduces their sugar content.
- **Impact on vegetation:** Temperature inversion can also impact orchards and other vegetation. For example, the lower valleys of the Alps Mountains have very few settlements, while the upper slopes are inhabited.
- **Cloud formation:** In areas with a pronounced low-level inversion, convective clouds cannot grow tall enough to produce showers.
- **Diurnal temperature variations:** Temperature inversion can also influence diurnal temperature variations, which tend to be minimal in such conditions.

Which of the following factors can cause temperature inversion? A. Stable atmospheric conditions **B.** Vertical movement of air **C.** Long nights and clear skies **D.** All of the above

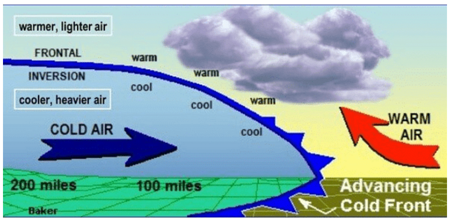
The ideal conditions for temperature inversion include long nights, clear skies, and calm, stable air. These conditions allow for greater outgoing radiation than incoming radiation, unobstructed escape of radiation, and minimal vertical mixing at lower levels.

Types of Temperature Inversion

- Frontal inversion
- Temperature Inversion in Intermontane Valley
- Ground Inversion
- Subsidence Inversion
- Marine Inversion

1. Frontal inversion

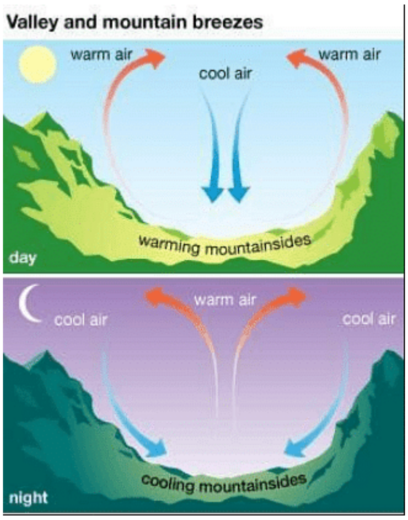
- Temperature inversion in temperate cyclones occurs due to the horizontal and vertical movement of air. These cyclones are created when warm westerly winds and cold polar air converge, resulting in warm air being positioned above cold air. This arrangement reverses the typical lapse rate, causing an inversion of temperature.
- In comparison to other inversions that are almost horizontal, this type of inversion has a significant slope. Additionally, humidity levels can be high, and clouds may form right above the inversion layer. However, this kind of inversion is unstable and will dissipate as weather conditions change.



Frontal Inversion

2. Temperature Inversion in Intermontane Valley (Air Drainage Type of Inversion)

- In some instances, the temperature in the lower layers of the atmosphere increases instead of decreasing as elevation rises. This phenomenon typically occurs along a sloped surface. During this process, the surface quickly radiates heat back into space, causing it to cool down faster than the layers of air above it. As a result, the lower, colder air layers become denser and heavier.
- Due to the sloping surface, this denser, colder air moves downward and settles at the bottom, forming a zone of low temperature. Meanwhile, the upper layers of air remain relatively warmer. This reversal of the typical vertical temperature distribution is known as Temperature Inversion, as the temperature profile becomes inverted.
- Temperature Inversion is particularly strong in middle and high latitudes and can also be pronounced in regions with tall mountains or deep valleys.



3. Ground Inversion (Surface Temperature Inversion)

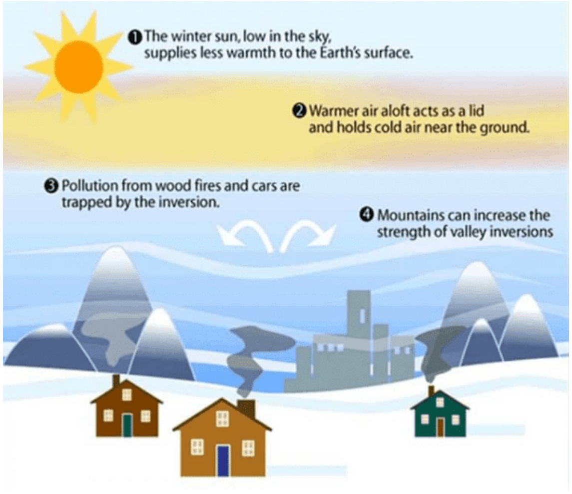
A ground inversion occurs when the air near the Earth's surface becomes cooler than the air above it, usually as a result of contact with a colder surface. This phenomenon is most commonly observed on clear nights when the ground loses heat rapidly through radiation, causing the surface air temperature to drop below its dew point and potentially leading to fog formation.

Ground inversions are particularly prevalent in higher latitude regions, while they can also be observed in lower and middle latitudes during cold nights. However, in these areas, the inversion typically dissipates with the sunrise. As one moves towards the poles, the duration and height of the surface inversion increase.

There are several conditions necessary for the formation of a ground surface inversion:

- Long winter nights with clear and calm skies
- Dry air and low relative humidity
- A calm atmosphere or slow-moving air
- A snow-covered surface

In summary, a ground inversion is a temperature inversion that develops when the air near the ground becomes cooler than the air above it, often on clear and cold nights. This phenomenon is more common in higher latitudes and requires specific conditions, such as clear skies, dry air, and slow-moving air, to occur.



Ground Inversion

4. Subsidence Inversion (Upper Surface Temperature Inversion)

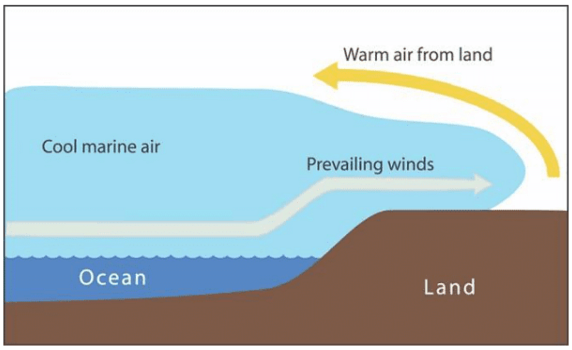
- A subsidence inversion occurs when a widespread layer of air descends in the atmosphere. As this layer descends, it becomes compressed and heated due to the increased atmospheric pressure. This process causes the temperature lapse rate, or the rate at which temperature decreases with altitude, to decrease as well.
- When the air mass sinks low enough, the air at higher altitudes becomes warmer than the air at lower altitudes, creating a temperature inversion.
- Subsidence inversions are commonly found over the northern continents during winter, when the atmosphere is dry, and over subtropical oceans. These areas typically experience subsiding air because they are situated under large high-pressure centers.
- The temperature inversion that occurs in these situations is referred to as an upper surface temperature inversion, as it takes place in the upper parts of the atmosphere.

5. Marine Inversion

- Marine inversions occur when cool, moist air from the ocean is blown onto the land by prevailing westerly winds. Due to the cool temperature of this air, it becomes

denser and easily flows beneath the warmer, drier air present over land.

- These inversions typically happen in areas close to large bodies of water, particularly during springtime when the water is at its coldest.
- As the air passes over the water, it cools down due to heat conduction from the air to the water. This cold air is then pushed inland, flowing underneath the warmer air over the land, resulting in a marine inversion.



Marine Inversion

Economic Implications of Temperature Inversion

- Sometimes, the air temperature in the bottom of valleys drops below freezing, while the air at higher altitudes remains relatively warm. This causes frost to form on trees along the lower slopes, while trees at higher levels remain unaffected. The inversion of temperature also leads to air pollutants, such as dust particles and smoke, being trapped in the valley bottoms, as they do not disperse properly.
- These factors contribute to the preference of building houses and farms on the upper slopes of intermontane valleys, as it helps avoid the cold and foggy conditions in the valley bottoms. For example, coffee growers in Brazil and apple growers and hotel owners in the mountain states of the Himalayas in India prefer to avoid the lower slopes for these reasons.
- Fog can also have negative impacts on both vegetation and human settlements, as it reduces visibility. Additionally, the stable conditions caused by temperature inversion can lead to less rainfall in these areas.

What are some negative effects of temperature inversion? A. Formation of fog and smog **B.** Increased road accidents **C.** Crop damage **D.** All of the above

Conclusion

Temperature inversion is a phenomenon where the typical pattern of temperature decrease with increasing altitude reverses, leading to warmer air above colder air. This can result in fog, reduced visibility, crop damage, and impacts on vegetation. There are various types of temperature inversions, such as frontal, intermontane valley, ground, subsidence, and marine inversions. These inversions can have significant economic implications, particularly in agriculture and human settlements, as they influence the preference for building houses and farms at certain elevations and can affect crop growth and overall weather conditions.

What is temperature inversion?

Temperature inversion, also known as thermal inversion, occurs when the usual pattern of temperature decrease with increasing altitude is reversed. Instead of the temperature dropping as we move higher up in the troposphere, it actually increases, resulting in a layer of warm air settled above a layer of colder air.

What causes temperature inversion?

There are several factors that can cause temperature inversion, such as stable atmospheric conditions or the horizontal or vertical movement of air. Some types of temperature inversions include frontal inversion, temperature inversion in intermontane valleys, ground inversion, subsidence inversion, and marine inversion.

What are the effects of temperature inversion on the environment?

Temperature inversion can have several negative effects on society and the economy in regions where it occurs. Some of the primary consequences of temperature inversion are the formation of fog, increased road accidents, crop damage, impact on vegetation, cloud formation, and altered diurnal temperature variations.

How does temperature inversion affect air quality?

Temperature inversion can lead to the trapping of air pollutants, such as dust particles and smoke, in the lower layers of the atmosphere. This is because the stable conditions created by the inversion prevent these pollutants from dispersing properly, leading to poor air quality and potential health hazards.

Can temperature inversion be a factor in climate change?

While temperature inversion is not a direct cause of climate change, it can contribute to the impacts of climate change by exacerbating

poor air quality and altering local weather patterns. Additionally, the stable conditions caused by temperature inversion can lead to less rainfall in certain areas, which can have implications for agriculture and water resources.

1. What is temperature inversion?

Ans. Temperature inversion refers to a deviation from the normal decrease in temperature with altitude in the Earth's atmosphere. Instead of the usual pattern where temperature decreases as altitude increases, temperature inversion occurs when the temperature increases with altitude. This inversion layer acts as a cap to trap pollutants close to the surface.

2. What are the effects of temperature inversion?

Ans. Temperature inversion can have various effects on the atmosphere and human activities. One of the significant effects is the trapping of pollutants, such as smog and harmful gases, near the ground. This can lead to poor air quality and respiratory issues. Temperature inversion can also affect weather patterns, causing fog, smog, or haze to persist for longer periods. Additionally, temperature inversion can impact aviation by creating turbulence and reducing visibility.

5. How does temperature inversion impact atmospheric stability and instability?

Ans. Temperature inversion plays a crucial role in determining atmospheric stability and instability. Inversion layers act as a lid, preventing vertical mixing of air masses. This stability inhibits the vertical transport of pollutants and can lead to the accumulation of pollutants close to the surface, resulting in poor air quality. On the other hand, when an inversion layer is disrupted or weakened, it can lead to instability, allowing for the vertical movement of air masses, leading to the formation of storms or severe weather conditions.

3. What are the types of temperature inversion?

Ans. There are four main types of temperature inversion: 1. Radiation Inversion: Occurs during calm and clear nights when the ground loses heat rapidly, causing the air near the surface to cool faster than the air above it. 2. Advection Inversion: Formed when warm air moves over a cool surface, causing the lower layer to cool and create an inversion. 3. Frontal Inversion: Associated with the passage of a warm or cold front, where warm air is lifted over cooler air, leading to an inversion. 4. Subsidence Inversion: Happens when a large-scale sinking motion in the atmosphere causes compression and warming of the air, resulting in an inversion layer.

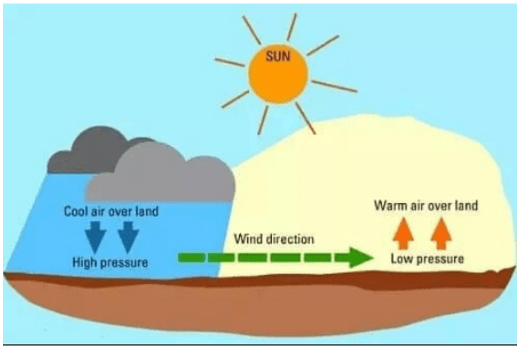
4. What are the economic implications of temperature inversion?

Ans. Temperature inversion can have various economic implications. Poor air quality caused by the trapping of pollutants can lead to health issues, resulting in increased healthcare costs. Industries that heavily rely on outdoor activities, such as tourism, agriculture, and construction, may suffer due to reduced visibility and adverse weather conditions caused by temperature inversion. Additionally, temperature inversion can impact energy consumption as it affects the dispersion of pollutants and the efficiency of power plants.

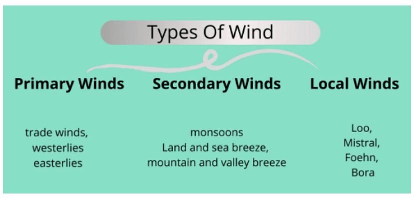
Planetary & Local Winds

Wind

Wind can be simply defined as the horizontal movement of air. This movement occurs due to variations in air pressure within our atmosphere. Air under high pressure tends to flow towards areas of low pressure. In this article, we will explore the various types of wind.



Types of Wind



Primary Winds, also known as Permanent, Prevailing, or Planetary Winds

These winds include the trade winds, westerlies, and easterlies, and they consistently blow in the same direction across the globe.

Secondary or Periodic Winds

- **Seasonal winds:** These winds shift their direction based on the season. A notable example is the monsoon winds in India, which change direction in different seasons.
- **Periodic winds:** These winds occur periodically, such as the land and sea breezes, as well as the mountain and valley breezes. Their occurrence depends on specific conditions like temperature and pressure differences.

Local Winds

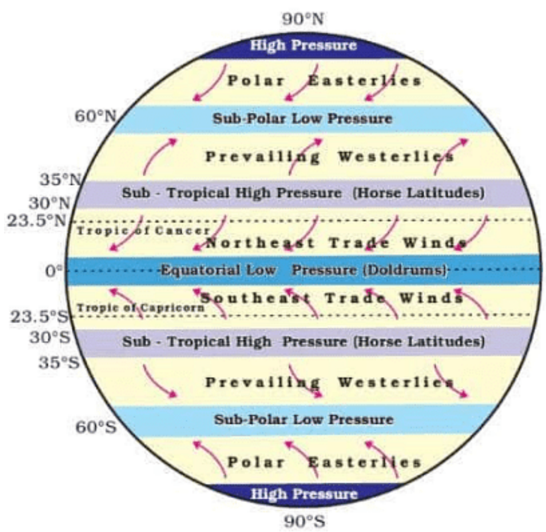
Local winds are specific to certain regions and typically blow during particular times of the day or year. Examples of local winds include the Loo, Mistral, Foehn, and Bora. These winds are influenced by local geographical features and weather patterns.

Primary Winds or Prevailing Winds or Permanent Winds

- These are the **planetary winds** which blow extensively over continents and oceans.
- The two most well- understood and significant winds for climate and human activities are **trade winds** and **westerly winds.**

Trade Winds

- The trade winds are winds that blow from the sub-tropical high-pressure zones towards the equatorial low-pressure belt, occurring between 30°N and 30°S across the Earth's surface. In the northern hemisphere, they are known as the north-eastern trade winds, while in the southern hemisphere, they are called the south-eastern trade winds. These winds were named "trade winds" due to their consistent and regular direction, which aided sea merchants in navigating their ships.
- The deflection of the trade winds from their expected north-south direction can be explained by the Coriolis force and Farrel's law. According to this law, trade winds in the northern hemisphere are deflected to the right, while those in the southern hemisphere are deflected to the left.
- At their origin in the sub-tropical high-pressure belt, trade winds are descending and stable. As they move towards the equator, they become warmer and more humid, picking up moisture along the way. When the trade winds from both hemispheres converge at the equator, they rise and produce heavy rainfall due to this convergence.
- The eastern parts of the trade winds, which are associated with cool ocean currents, tend to be drier and more stable than the western parts of the ocean. Overall, the trade winds play a significant role in global weather patterns and have been historically important for navigation and trade.



Major Pressure Belts & Wind System

Westerlies

- The westerlies are winds that blow from the subtropical high-pressure belts (located at 30°-35° latitude) towards the sub-polar low-pressure belts (located at 60°-65° latitude) in both the northern and southern hemispheres. In the northern hemisphere, these winds blow from the southwest to the northeast, while in the southern hemisphere, they blow from the northwest to the southeast.

- The southern hemisphere's westerlies are more powerful and consistent, largely due to the vast expanse of water in that region. In contrast, the northern hemisphere's westerlies are less regular due to the uneven distribution of large landmasses. As a result, the westerlies in the northern hemisphere are less effective during the summer and more vigorous during the winter.
- The westerlies are responsible for bringing significant precipitation to the western parts of continents, such as the northwest coasts of Europe. This is because they collect moisture as they pass over the oceans. In the southern hemisphere, the westerlies become even more forceful due to the lack of land and dominance of the oceans. Their speed increases as they move southward, often resulting in stormy, gale-force winds.
- The westerlies are most prominent between 40° and 65°S latitudes, which are often referred to as the Roaring Forties, Furious Fifties, and Shrieking Sixties – terms that strike fear into the hearts of sailors. The poleward boundary of the westerlies is subject to significant fluctuations, both seasonally and in the short term. These winds are responsible for creating wet weather and variable conditions.

Polar easterlies

- The Polar easterlies are dry and cold winds that predominantly blow from the north-east to the south-west direction in the Northern Hemisphere, and from the south-east to the north-west direction in the Southern Hemisphere.
- These winds originate from the high-pressure polar regions and move towards the lower pressure sub-polar areas.

What are the main factors that cause the formation of land and sea breezes?

A. Differences in the pressure and humidity of air above land and sea
B. Differences in the way land and sea absorb and release heat
C. Differences in the direction of trade winds and polar easterlies
D. Differences in the latitude and longitude of land and sea

Secondary Winds or Periodic Winds

- These winds **change their direction with change in season.**
- **Monsoons** are the best example of large-scale modification of the planetary wind system.
- Other examples of periodic winds include **land and sea breeze, mountain and valley breeze, cyclones and anticyclones, and air masses.**

Monsoons

- Monsoons are large-scale weather patterns characterized by a seasonal reversal of wind direction. They were traditionally understood as land and sea breezes on a grand scale, resulting in convectional circulation.
- During the summer season, the southern hemisphere's trade winds are drawn northwards due to the sun's apparent northward movement and the presence of an intense low-pressure core in the northwestern region of the Indian subcontinent. As these winds cross the equator, the Coriolis force deflects them to the right, causing them to approach the Asian landmass as southwest monsoons. Since these winds travel a long distance across a vast expanse of water, they become saturated with moisture by the time they reach India's southwestern coast, resulting in heavy rainfall in India and neighboring countries.
- In contrast, during the winter season, a high-pressure core forms to the north of the Indian subcontinent, generating divergent winds that travel southwards towards the equator. This movement is reinforced by the sun's apparent southward movement. These northeast or winter monsoons cause some precipitation along the east coast of India.
- Monsoon winds affect regions such as India, Pakistan, Bangladesh, Myanmar (Burma), Sri Lanka, the Arabian Sea, the Bay of Bengal, Southeast Asia, Northern Australia, and China. In eastern Asian countries like China and Japan, the winter monsoon is more powerful than the summer monsoon. More information about monsoons will be covered in the study of Indian climate.

Land Breeze and Sea Breeze

- Land and sea breezes are phenomena that occur due to the different ways in which land and sea absorb and release heat. During the daytime, the land heats up more quickly and becomes warmer than the sea. As a result, the air above the land rises, creating a low-pressure area, while the cooler sea has a relatively high-pressure area. This pressure difference causes the wind to blow from the sea toward the land, creating a sea breeze.

- Conversely, at night, the situation is reversed. The land cools down more rapidly than the sea, making it cooler in comparison. This leads to a pressure gradient from the land to the sea, and as a result, the wind blows from the land towards the sea, creating a land breeze.

Valley Breeze and Mountain Breeze

- In areas with mountains, the air circulation patterns differ from those in flat regions. During the day, the sun heats the mountain slopes, causing the air to rise and creating an upward movement of air known as an upslope wind. To fill the empty space left behind, air from the valley flows upwards, creating a wind called the valley breeze.
- At night, the situation reverses. The mountain slopes cool down, causing the air to become denser and descend into the valley. This downward movement of air is called mountain wind or katabatic wind. It consists of cold air from high plateaus and ice fields flowing into the valley.
- Another type of katabatic wind can be found on the side of the mountain range that is sheltered from the wind, known as the leeward side. As these winds cross the mountain range, their moisture condenses and precipitates. When the now-dry air descends the leeward slope, it warms up through a process called adiabatic heating. This warm, dry air can cause snow to melt rapidly.

Tertiary Winds or Local Winds

- Local differences in temperature and pressure produce local winds.
- Such winds are local in extent and are confined to the lowest levels of the troposphere. Some examples of local winds are discussed below.

Loo

- **Harmful Wind**
- In the plains of northern India and Pakistan, sometimes a very hot and dry wind blows from the west in the months of **May and June**, usually in the afternoons. It is known as Its temperature invariably ranges between **45°C and 50°C**. It may cause **sunstroke** to people.

Foehn or Fohn

- Foehn, also known as Fohn, is a type of local wind that occurs in the Alps. This wind is characterized by its strong, gusty, dry, and warm nature, which is a result of its formation on the leeward side of a mountain range.
- As the windward side of the mountain absorbs moisture through orographic precipitation, the air that descends on the leeward side becomes warm and dry, forming the Foehn wind. This wind typically has a temperature ranging from 15°C to 20°C.
- The Foehn wind offers several benefits to the local environment, such as melting snow to provide grazing areas for animals and aiding in the ripening of grapes. Overall, this unique wind plays a significant role in the climate and ecology of the Alpine region.

Chinook

- **Beneficial Wind**
- Foehn like winds in **USA and Canada** move down the west slopes of the **Rockies** and are known as
- It is **beneficial to ranchers** east of the Rockies as it keeps the grasslands clear of snow during much of the winter.

Mistral

- **Harmful Wind**
- Mistral is one of the local names given to such winds that blow from the Alps over France towards the Mediterranean Sea.
- It is channeled through the Rhine valley. It is **very cold and dry with a high speed**.
- It brings blizzards into southern France.

Sirocco

- The Sirocco is a powerful wind originating from the Mediterranean region, specifically from the Sahara Desert, that can reach hurricane-level speeds in North Africa and Southern Europe. This wind is formed when a warm, dry, tropical air mass is drawn northward by low-pressure cells moving eastward across the Mediterranean Sea. The source of the Sirocco lies in the Arabian or Sahara deserts.
- When the hot, dry continental air comes into contact with the cooler, wetter air of a maritime cyclone, the two air masses mix. The low-pressure system's counter-clockwise circulation then pushes this mixed air towards the southern coasts of Europe.
- As a result, the Sirocco brings about various weather conditions, such as dry and dusty conditions along the

northern African coast, storms within the Mediterranean Sea, and cool, wet weather throughout Europe.

Table of Major Local Wind Systems

Brickfielder	Very hot north-east summer wind that blows dust and sand across Australia.
Chinook	Warm, dry wind of the Rocky Mountains, USA. Welcomed by cattlemen because it can remove snow cover very quickly. Named after a local Indian tribe.
Foehn	Warm, dry European wind that flows down the side of mountains.
Haboob	The Arabic name for a violent wind which raises sandstorms, especially in North Africa.
Levanter	Pleasant, moist east wind that brings mild weather to the Mediterranean.
Mistral	Violent, dry, cold, north-west wind that blows along the coasts of Spain and France.
Sirocco	The hot, dry South wind that blows across North Africa from the Sahara. Becomes very hot and sticky as it reaches the sea.
Elephanta	Malabar coast; South easterly wind; Marks end of southwest monsoon
Nor' easter	Northeast USA; Strong storm winds from the northeast
Nor' wester	East coast of New Zealand; Warm dry winds
Santa-Ana winds	Southern California Strong, extremely dry winds; Responsible for frequent wildfires
Shamal	Persian Gulf; Strong Northwesterly wind; Causes large sandstorms in Iraq
Calima	Sahara to Canary Islands (west African coast); Carries dust from the Sahara

How is Wind Measured?

The wind has speed as well as direction, to measure this parameter, two different devices are used

- Anemometers
- Wind vanes

Anemometers: is used for measuring the speed of the wind.
Wind vanes: is used for determining the direction of the wind.

Causes of Wind

The main cause of generation of wind is the uneven heating of two regions.

Examples

- Uneven heating between land and sea
- Uneven heating between equator and pole

Which type of wind is characterized by seasonal reversal of wind direction and is particularly significant in regions like India and Southeast Asia? **A.** Trade winds **B.** Westerlies **C.** Monsoons **D.** Polar easterlies

Conclusion

Wind can be simply defined as the horizontal movement of air due to variations in air pressure within our atmosphere. There are various types of winds, including primary winds (such as trade winds and westerlies), secondary winds (like monsoons and land/sea breezes), and local winds (such as Loo, Mistral, Foehn, and Bora). These winds play a significant role in shaping global weather patterns and climate, as well as impacting human activities like navigation and trade. The measurement of wind involves anemometers for speed and wind vanes for direction, and the primary cause of wind generation is the uneven heating of different regions.

What are the primary factors that cause wind?

The main factors that cause wind are uneven heating of the Earth's surface, which leads to variations in air pressure within the atmosphere. Air under high pressure tends to flow towards areas of low pressure, resulting in the movement of air known as wind.

What are the differences between primary, secondary, and tertiary winds?

Primary winds, also known as permanent, prevailing, or planetary winds, are consistent winds that blow in the same direction across the globe, such as trade winds, westerlies, and easterlies. Secondary winds, or periodic winds, change their direction based on specific conditions, like temperature and pressure differences, or seasons, such as monsoons, land and sea breezes, and mountain and valley breezes. Tertiary winds, or local winds, are specific to certain regions and typically blow during particular times of the day or year, influenced by local geographical features and weather patterns.

What is the role of the Coriolis force in the movement of winds?

The Coriolis force is a result of the Earth's rotation and affects the movement of winds by deflecting their path. In the northern hemisphere, the Coriolis force causes winds to be deflected to the right, while in the southern hemisphere, winds are deflected to the left. This deflection plays a significant role in the formation and direction of primary winds, such as trade winds and westerlies.

How do monsoon winds affect the climate of regions like India?

Monsoon winds have a significant impact on the climate of regions like India, as they bring heavy rainfall and influence temperature variations. During the summer season, the southwest monsoons bring warm, moist air from the Indian Ocean, causing heavy rainfall in India and neighboring countries. In contrast, the winter monsoons bring cooler, drier air from the north, causing milder precipitation along the east coast of India. These seasonal wind changes heavily influence the agriculture and water resources of the region.

How can local winds like Foehn and Mistral impact the environment and human activities?

Local winds like Foehn and Mistral can have both positive and negative impacts on the environment and human activities. The Foehn wind, for example, can help melt snow in the Alpine region, providing grazing areas for animals and aiding in the ripening of grapes. However, the Mistral wind, which is cold, dry, and high-speed, can bring blizzards into southern France, causing challenges for agriculture and transportation.

1. What are primary winds or prevailing winds?

Ans. Primary winds or prevailing winds are the dominant winds that blow consistently over a particular region or area. These winds are influenced by global atmospheric circulation patterns and are responsible for shaping the climate of the region. Examples of prevailing winds include the trade winds, westerlies, and polar easterlies.

2. What are secondary winds or periodic winds?

Ans. Secondary winds or periodic winds are winds that occur periodically or seasonally in specific areas. Unlike prevailing winds, these winds are not dominant and are often influenced by local factors such as temperature, topography, and local pressure systems. Examples of periodic winds include monsoons, sea breezes, and land breezes.

3. How do primary winds differ from secondary winds?

Ans. Primary winds, also known as prevailing winds, are the dominant winds that blow consistently over a specific region and are influenced by global atmospheric circulation patterns. On the other hand, secondary winds, also known as periodic winds, occur periodically or seasonally and are influenced by local factors such as temperature, topography, and local pressure systems. While primary winds shape the long-term climate patterns, secondary winds bring temporary changes in weather conditions.

4. What is the significance of planetary and local winds?

Ans. Planetary and local winds play a crucial role in shaping the climate and weather conditions of a region. Prevailing winds, such as the trade winds and westerlies, distribute heat and moisture across the Earth's surface, influencing temperature, rainfall patterns, and vegetation distribution. Secondary winds, such as monsoons and sea breezes, bring seasonal changes in weather, affecting agriculture, transportation, and overall livelihoods in the area.

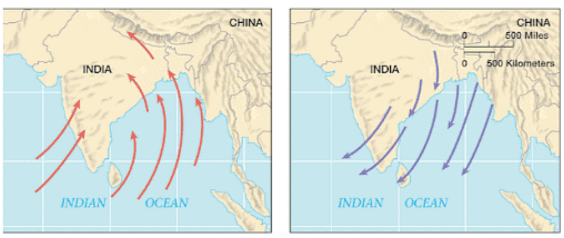
5. How do planetary and local winds impact human activities?

Ans. Planetary and local winds have significant impacts on various human activities. For example, prevailing winds are utilized in sailing and navigation, enabling efficient travel across oceans and seas. Local winds, such as monsoons, are crucial for agriculture as they bring much-needed rainfall during specific seasons. Winds also play a role in generating wind energy, which is harnessed through wind turbines for electricity production. Additionally, winds influence air pollution dispersion and affect aviation operations.

Monsoon & Jet Streams

Indian Monsoon

- The term 'monsoon' is thought to have originated from the Arabic word for season, 'mawsim'. Monsoons are essentially seasonal winds that change direction based on the season, making them periodic winds. These winds travel from the sea to the land during summers and from land to the sea during winters, creating a dual system of seasonal winds. Some experts consider monsoon winds to be large-scale land and sea breezes.
- Historically, monsoons have been crucial for traders and sailors, who used these winds to travel from one place to another. Though monsoons occur in the Indian subcontinent, central-western Africa, Southeast Asia, and a few other locations, they are most prominent in the Indian subcontinent.
- India experiences southwest monsoon winds during summers and northeast monsoons during winters. The former is caused by the formation of a strong low-pressure system over the Tibetan Plateau, while the latter is due to the high-pressure cells formed over the Siberian and Tibetan plateaus. The southwest monsoons bring heavy rainfall to most parts of India, while the northeast monsoons primarily bring rainfall to the southeastern coast of India, such as the southern coast of Andhra Pradesh and the coast of Tamil Nadu.
- Countries like India, Indonesia, Bangladesh, and Myanmar receive most of their annual rainfall during the southwest monsoon season, whereas southeast China and Japan receive their rainfall during the northeast monsoon season.

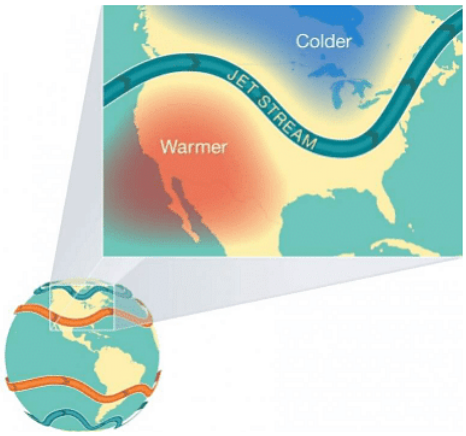


Summer Winter

Summer Monsoon	Winter Monsoon
(i) They blow during the months of June to September.	(i) They blow during the months of December to February.
(ii) These blow from the high pressure area on the sea to the low pressure area on the land.	(ii) These blow from the high pressure area on land to the low pressure area on the sea.
(iii) These bring rain to the greater part of India.	(iii) These bring a little rain only to the Tamil Nadu coast.
(iv) These blow into India in two branches, *i.e.*, the Arabian Sea and the Bay of Bengal branches.	(iv) These have only one branch.

Jet Streams

Jet streams are powerful, fast-moving winds that flow in narrow bands within the upper atmosphere's westerlies. These bands can range from 160-480 km in width and 900-2150 m in thickness, with core speeds surpassing 300 km/hr. Due to their impressive strength, aircraft routes that go against jet stream movements are typically avoided. Jet streams are often found in areas where there are significant breaks in the tropopause.

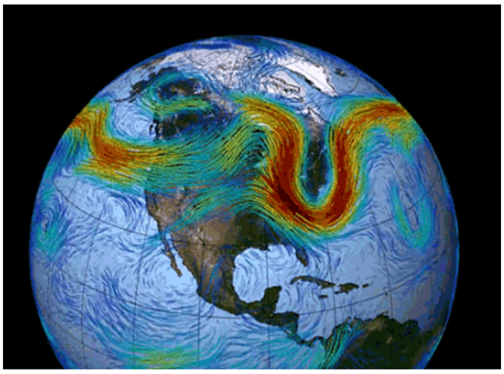


- A jet stream is a geostrophic wind that flows horizontally through the upper levels of the troposphere, typically blowing from west to east. These jet streams form at the boundaries where air masses with different temperatures meet, with surface temperatures usually determining their location.
- The greater the temperature difference between the air masses, the faster the wind velocity within the jet stream. Jet streams extend from latitudes of around 20 degrees to the poles in both the Northern and Southern Hemispheres.

What factors influence the flow of jet streams? A. Landmasses **B.** Coriolis effect **C.** Temperature variations **D.** All of the above

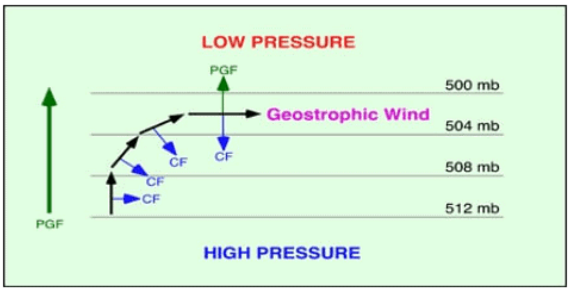
What is Jet Stream?

- Jet streams are narrow, fast-moving bands of air that circle around the Earth's poles in the upper atmosphere. These powerful wind currents are part of the westerly winds and are characterized by their high velocity and meandering patterns.
- They are surrounded by slower-moving winds and play a significant role in shaping weather patterns across the globe.



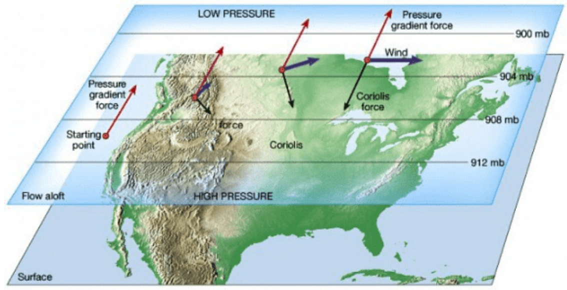
Geostrophic Wind

The geostrophic wind is a theoretical concept that describes the wind's velocity and direction when it is solely influenced by the balance between the Coriolis force and the pressure gradient force. This phenomenon typically occurs in the upper atmosphere, around 2-3 kilometers above the earth's surface, where the frictional effects of the surface are minimal.

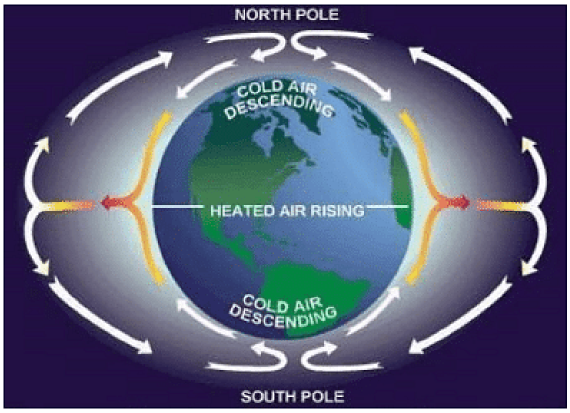


Geostrophic Wind

- When air parcels start to move from high-pressure areas to low-pressure areas due to the pressure gradient force (PGF), they are deflected by the Coriolis force. In the northern hemisphere, this deflection occurs to the right, while in the southern hemisphere, it occurs to the left. As the wind's speed increases, so does the deflection, until the Coriolis force and the pressure gradient force reach equilibrium.
- At this point, the wind flows parallel to the isobars (the lines connecting points of equal atmospheric pressure) and perpendicular to the pressure gradient force. This specific wind condition, where the forces are balanced, is referred to as the geostrophic wind.



Why winds don't flow from tropical high pressure (in upper troposphere) to polar low (in upper troposphere) directly as shown in the figure below?



- Geostrophic winds, which flow rapidly due to reduced friction and experience a significant Coriolis force, are responsible for the creation of three distinct atmospheric circulation cells: the Hadley cell, Ferrel cell, and Polar cell.
- Instead of having one large cell, these three smaller cells together generate the same overall effect in distributing heat and driving global atmospheric circulation.
- The presence of these cells can be attributed to the strong deflection caused by the Coriolis force acting on the high-speed geostrophic winds.

Genesis of Jet Streams

The genesis of the Jet-streams is provided by three kinds of gradients:

- The thermal gradient between pole and equator
- The pressure gradient between pole and equator
- The pressure gradient between surface and subsurface air over the poles.

Characteristics of Jet Stream

Jet streams are characterized by their high-velocity winds,

which can reach speeds of 400-500 km/h. These impressive speeds are a result of the significant thermal contrasts that create a powerful pressure gradient force.

- These strong winds do not follow a straight path; instead, they meander, encircling the globe in a curved trajectory. The flow of jet streams is three-dimensional, causing crests and troughs to develop along their course.
- In terms of size and dimension, jet streams can span hundreds of kilometers in width and thousands of kilometers in length. Specifically, they typically have a width of 10-12 km, a depth of 2-3 km, and a length of around 3,000 km. Jet streams are found at altitudes just below the tropopause, which is the boundary between the troposphere and stratosphere.
- Jet streams also exhibit seasonal variations, shifting their positions in response to the apparent movement of the sun. They consistently travel from west to east in both the Northern and Southern Hemispheres.

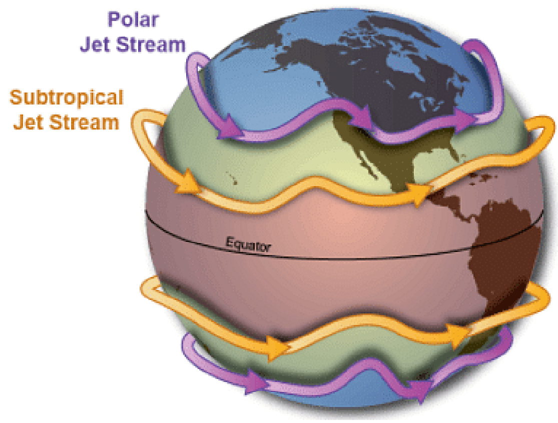
thermal contrast

Types of jet Streams

- Polar front jet streams
- Subtropical Westerly Jet streams
- Tropical easterly Jet streams
- Polar night Jet Streams
- Local Jet Streams

Permanent jet streams – subtropical jets at lower latitudes and **polar front jets** at mid latitudes.
Temporary jet streams – Tropical Easterly Jet or African Easterly Jet ,and Somali Jet (southwesterly).

1. **Polar Front Jet Streams**
    - Formed above the convergence zone (40-60 degree) of surface polar cold air mass and tropical warm air mass
    - These move in easterly direction but are irregular



2. **Subtropical Westerly jet Streams**
    - Formed above 30-35 latitude
    - Move-in upper troposphere to the north of the subtropical surface high-pressure belt
    - Also known as stratospheric subpolar jet streams
3. **Tropical Easterly jet streams**

    Develop in upper troposphere above surface easterly trade winds over India and Africa during the summer season due to intense heating of Tibetan plateau and play an important role in Indian Monsoon
4. **Polar Night Jet Streams**

    Develop in winter season due to steep temperature gradient in the stratosphere around the poles
5. **Local Jet Streams**

    Formed locally due to local thermal and dynamic conditions and have limited local importance.

Index Cycle of Jet Streams

Stage 1

- In subpolar low-pressure belt, the cold air from poles and warm air from subtropics converge along a horizontal line
- Due to the great thermal contrast and differences in the physical properties, they don't mix up.
- A zone of the stationery situation is created between these 2 air masses

Stage 2

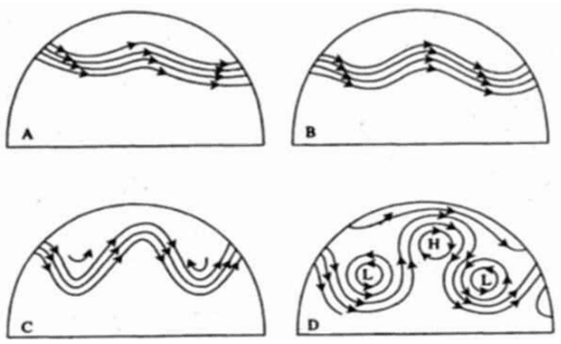
- Cold polar air is pushed by the easterlies and warm air is pushed by westerlies.
- The stationary situation is transformed into an oscillating wave. These are known as Rossby waves

Stage 3

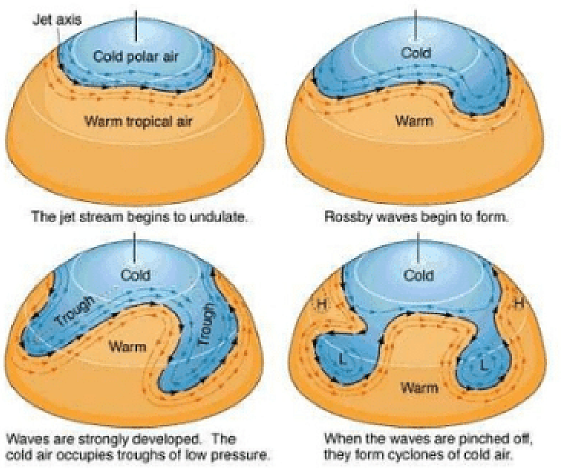
- Cold and warm air further invades each other territory and waves further meander.
- Jet streams of high sinuosity develop and attain maturity

Stage 4

- cold air mass moves into warm air and latitudinal heat exchange occurs.
- The stationary front situation is reattained.



index cycle of Jet stream



Significance of jet streams

- Jet streams play a significant role in the intensity of mid-latitude cyclones, as these fast-moving air currents in the upper troposphere can amplify the strength and storminess of temperate cyclones when they are positioned above them.
- Additionally, jet streams have a major influence on South Asia's monsoon, as they largely control and impact the weather patterns associated with the monsoon season.

Factors affecting the Jet Stream Flow

- The jet stream flow is influenced primarily by two factors: landmasses and the Coriolis effect. Landmasses interfere with the jet stream's flow due to friction and temperature variations, while the Earth's rotation accentuates these changes. As a result, the jet stream moves across the planet in a meandering pattern, similar to how a river flows before reaching the ocean.
- These winding segments of the jet stream constantly transform as they interact with different landmasses, leading to an ever-evolving flux of temperature variations. During winter, the stratosphere's temperature can also impact the jet stream's strength and position. A colder polar stratosphere results in a more pronounced temperature difference between polar and tropical regions, causing the jet stream to become more powerful.
- Additionally, the warmth of landmasses and oceans, such as the El Niño Southern Oscillation, can influence the jet stream's strength and amplitude. Overall, the jet stream's flow is affected by a combination of factors, including landmasses, the Coriolis effect, and temperature variations.

Jet streams & the weather

- Jet streams have a significant impact on weather patterns as they typically separate colder and warmer air masses. These fast-moving air currents help to move weather systems from one area to another and can even cause them to stall if they have traveled too far.
- Climate experts have found strong links between changes in jet streams and global warming, particularly in relation to the polar jet streams. This is because there is substantial evidence indicating that the North and South poles are warming more rapidly than the rest of the Earth.
- As jet streams become warmer, their fluctuations become more severe, leading to unusual weather patterns in areas that are generally unaccustomed to such variations. For instance, if a jet stream shifts towards the south, it carries the colder air mass along with it. This results in the spread of colder temperatures to regions that typically do not experience such conditions.

Air travel

- Jet streams significantly impact air travel, as they are fast-moving air currents that can affect flight times and safety. When flying eastward, aircraft often experience shorter flight durations due to the assistance of these high-speed winds. However, westbound flights typically take longer as they must travel against the force of the jet streams.

- One of the major threats posed by jet streams to air travel is wind shear, a sudden and violent shift in wind speed and direction.
- This phenomenon can cause planes to unexpectedly lose altitude, increasing the risk of crashing. In response to this danger, the Federal Aviation Administration (FAA) mandated in 1988 that all commercial aircraft be equipped with wind-shear warning systems. However, it took until 1996 for all airlines to fully implement these safety measures on their planes.

Jet Streams affecting the Monsoons and the Indian Sub Continent

- Jet streams, specifically the Subtropical Jet Stream (STJ) and the opposing easterly jet, play a significant role in the monsoon patterns and overall climate of India. The STJ has a considerable impact on the development of summer monsoons.
- As the Indian subcontinent experiences increased solar heating during the approach of summer, a cyclonic monsoon cell tends to form between the Indian Ocean and southern Asia. The development of this cell, however, is hindered by the STJ, which typically blows to the south of the Himalayas.
- During summer, the STJ shifts its course northwards and moves across the Himalayas. Although the jet stream is initially disrupted by the high altitude of the mountains, it reforms over central Asia after crossing the range. With the STJ out of the way, the monsoon cell in the subcontinent rapidly develops, often in just a few days.
- The lower level tropical jet stream supplies warmth and moisture to the monsoon cell, transporting air masses filled with moisture from the Indian Ocean. As these air masses encounter the mountainous terrain of northern India, they are forced upward, causing the air to cool and compress. This process results in the air reaching its saturation vapor point and releasing the excess moisture as monsoon rains.
- The monsoon season comes to an end when the atmosphere over the Tibetan Plateau cools down, allowing the STJ to move back across the Himalayas. This shift leads to the formation of a winter monsoon cell characterized by sinking air masses over India and relatively dry winds blowing towards the sea. Consequently, India experiences more settled and dry weather during the winter months.

How do jet streams affect monsoons in the Indian subcontinent?

A. Jet streams block the development of monsoon cells

B. Jet streams shift northwards during summer, allowing monsoon cells to develop

C. Jet streams supply warmth and moisture to the monsoon cells

D. Both (B) and (C)

Conclusion

Jet streams and monsoons play significant roles in shaping global weather patterns and influencing the climate of various regions. Jet streams are powerful, fast-moving air currents in the upper atmosphere that affect air travel and weather systems, while monsoons are seasonal winds that bring heavy rainfall to countries like India, Indonesia, Bangladesh, and Myanmar. Both phenomena are interconnected and impact each other, particularly in the Indian subcontinent where the jet streams help regulate the monsoon seasons. Understanding these atmospheric processes is crucial for predicting and adapting to changing weather patterns and the effects of climate change.

What is the origin of the term 'monsoon,' and how does it affect the Indian subcontinent?

The term 'monsoon' is believed to have originated from the Arabic word for season, 'mawsim.' Monsoons are seasonal winds that change direction based on the season. In India, the southwest monsoon winds bring heavy rainfall during summers, while the northeast monsoon winds bring rainfall primarily to the southeastern coast during winters. These monsoons play a crucial role in India's climate and agriculture.

What is a jet stream, and how does it affect global weather patterns?

Jet streams are narrow, fast-moving bands of air that circle around the Earth's poles in the upper atmosphere. They are part of the westerly winds and are characterized by their high velocity and meandering patterns. Jet streams play a significant role in shaping weather patterns across the globe, as they help move weather systems from one area to another, and can even cause them to stall.

What is geostrophic wind, and how does it relate to jet streams?

Geostrophic wind is a theoretical concept that describes the wind's velocity and direction when it is solely influenced by the balance between the Coriolis force and the pressure gradient force. This phenomenon typically occurs in the upper atmosphere, where the frictional effects of the surface are minimal. Jet streams are a type of geostrophic wind that flows horizontally through the upper levels of the troposphere.

How do jet streams affect air travel?

Jet streams impact air travel significantly, as their high-speed winds can affect flight times and safety. Eastward flights often experience shorter flight durations due to the assistance of jet streams, while westbound flights take longer as they must travel against the force of the jet streams. Wind shear, a sudden and violent shift in wind speed and direction, is a major threat posed by jet streams to air travel, as it can cause planes to unexpectedly lose altitude, increasing the risk of crashing.

How do jet streams influence monsoons and the climate of the Indian subcontinent?

The Subtropical Jet Stream (STJ) plays a significant role in the development of summer monsoons in India. As the STJ shifts its course northwards during summer, it allows the monsoon cell in the subcontinent to rapidly develop, bringing heavy rainfall. The lower level tropical jet stream supplies warmth and moisture to the monsoon cell, resulting in monsoon rains. The monsoon season ends when the STJ moves back across the Himalayas, leading to the formation of a winter monsoon cell and more settled and dry weather during the winter months.

1. What is the Indian Monsoon?

Ans. The Indian Monsoon refers to the seasonal reversal of wind patterns and the associated rainfall over the Indian subcontinent. It is characterized by the southwest monsoon winds, which bring heavy rainfall to the region during the summer months of June to September.

2. How does the Indian Monsoon affect agriculture in India?

Ans. The Indian Monsoon plays a crucial role in determining the agricultural output in India. The timely arrival and distribution of monsoon rains are essential for the growth of crops. Adequate rainfall supports the cultivation of various crops and helps replenish water reservoirs, ensuring irrigation during the dry season.

3. What are jet streams and how do they influence the Indian Monsoon?

Ans. Jet streams are high-altitude, narrow currents of strong winds in the atmosphere. The northern hemisphere has two main jet streams, namely the subtropical jet stream and the polar jet stream. These jet streams have a significant impact on the Indian Monsoon by influencing the movement and intensity of weather systems.

4. What is the cycle of jet streams and how does it affect weather patterns?

Ans. The cycle of jet streams refers to the seasonal shift in their positions. During winter, the polar jet stream is stronger and located at lower latitudes, while the subtropical jet stream is weaker and located at higher latitudes. In summer, this pattern reverses. These shifts in the jet stream positions influence the movement of weather systems and can lead to changes in temperature, precipitation, and storm patterns.

5. How do jet streams impact aviation and air travel?

Ans. Jet streams have a significant impact on aviation and air travel. Flying with the jet stream can result in faster travel times and fuel savings for aircraft, while flying against the jet stream can lead to longer flight durations and increased fuel consumption. Pilots and airlines often take jet streams into account when planning routes to optimize flight efficiency.

Temperate & Tropical Cyclones

Tropical Cyclones

Tropical cyclones are powerful storms that form over oceans in tropical regions and move towards coastal areas, causing widespread destruction due to strong winds, heavy rainfall, and storm surges. These storms involve a closed air circulation pattern around a low-pressure center, resulting from the rapid upward movement of warm air and the influence of the Coriolis force. The low pressure at the center of the storm leads to high wind speeds.

- A squall refers to a sudden, violent gust of wind or a localized storm that can bring rain, snow, or sleet. A torrent is a fast-moving, powerful stream of water or another liquid.
- The direction of cyclonic wind movements depends on the hemisphere: they are counterclockwise in the northern hemisphere and clockwise in the southern hemisphere. This is due to the Coriolis force. Cyclones are often found with an anticyclone situated between two cyclones.
- Tropical cyclones typically form around the equator between 5° and 30° latitude and have different names depending on where they develop in the world. On average, a tropical cyclone can travel about 300 to 400 miles per day or around 3,000 miles before dissipating.

Conditions Favorable for Tropical Cyclone Formation

- **Warm ocean waters with a temperature of at least 27° C (80° F) or higher:** Tropical cyclones require a large expanse of warm water to supply the necessary heat and moisture to fuel the storm. Warm waters help the air above them to rise, creating an area of low pressure at the surface.
- **Sufficient Coriolis effect to initiate a cyclonic rotation:** The Coriolis force, caused by the Earth's rotation, is necessary for the development of a rotating storm system. This force is stronger at higher latitudes and weaker near the equator. Tropical cyclones typically form at least 5° away from the equator to ensure there is enough Coriolis effect to initiate rotation.
- **Minimal vertical wind shear:** Wind shear refers to the change in wind speed and direction with height in the atmosphere. For tropical cyclones to form and intensify, the wind shear should be low. High vertical wind shear can disrupt the cyclone's structure by preventing the storm's warm core from developing or by tilting the storm, which weakens it.
- **An existing disturbance or low-pressure system:** Tropical cyclones often form from pre-existing weather disturbances, such as tropical waves or weak areas of low pressure. These disturbances provide an initial area of low pressure and convergence, which allows moist air to rise and start the process of cyclone formation.
- **Favorable upper-level atmospheric conditions:** Tropical cyclones require upper-level divergence, meaning that air must be able to spread out and move away from the storm at high altitudes. This allows more air to rise from the surface, maintaining the low pressure at the center of the storm and fueling its growth. Upper-level high-pressure systems or anticyclones can help provide the necessary divergence for tropical cyclone formation.

Good Source of Latent Heat

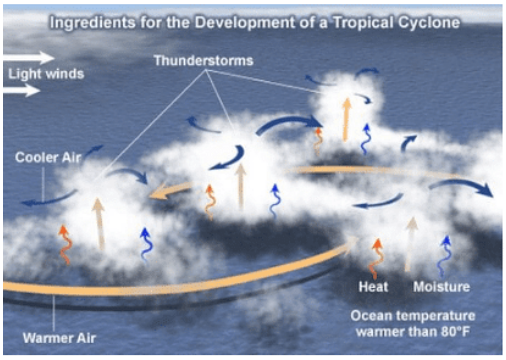
- Ocean waters with temperatures of 27°C or higher serve as a good source of latent heat, as they provide the moisture needed to fuel storms. The condensation of this moisture releases a significant amount of latent heat of condensation, which drives the storm's development. To maintain this heat source, it is essential that the warm water (26-27°C) extends to a depth of 60-70 meters from the ocean's surface. This depth prevents deep convection currents within the water from mixing cooler water below with the warmer water near the surface.
- This condition is primarily found in the western tropical oceans due to the warm ocean currents that flow from east to west, pushed by easterly trade winds. These currents form a thick layer of water with temperatures greater than 27°C, providing sufficient moisture for storm formation. On the other hand, cold currents in the eastern parts of the tropical oceans reduce surface temperatures, making these regions unsuitable for cyclonic storm development.

Coriolis Force (f)

- The **Coriolis force is zero at the equator (no cyclones at the equator because of zero Coriolis Force)** but it increases with latitude. Coriolis force at **5°** latitude is significant enough to create a storm [cyclonic vortex].
- **About 65 percent of cyclonic activity occurs between 10° and 20° latitude.**

Low-level Disturbances

- Low-level disturbance (thunderstorms – they are the seeds of cyclones) in the form of easterly wave disturbances in the Inter-Tropical Convergence Zone (ITCZ) should pre-exist.



- **Small local differences** in the temperature of the water and of air produce various **low-pressure centers** of small size. A weak cyclonic circulation develops around these areas.
- Then, because of the rising warm humid air, a true cyclonic vortex may develop very rapidly. However, only a few of these disturbances develop into cyclones.

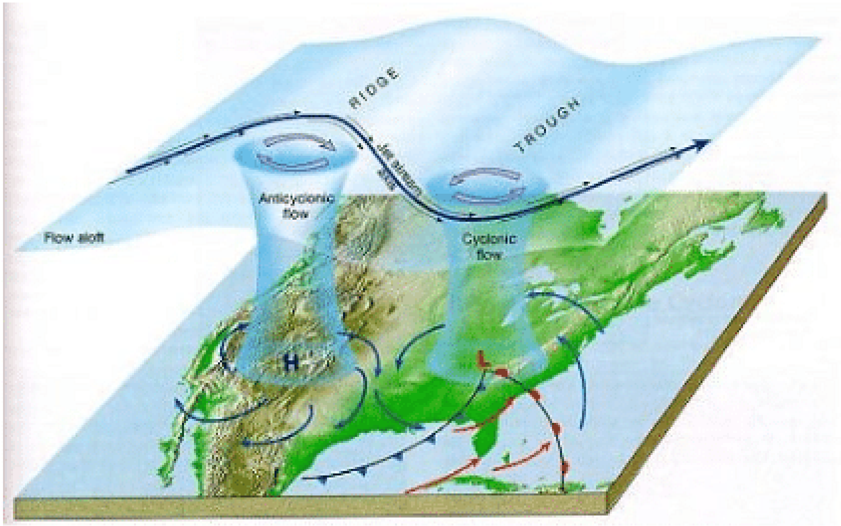
[rising of humid air → adiabatic lapse rate → fall in temperature of air → condensation of moisture in air → latent heat of condensation released → air gets more hot and lighter → air is further uplifted → more air comes in to fill the gap → new moisture available for condensation → latent heat of condensation and the cycle repeats]

Temperature contrast between air masses

- Trade winds from both hemispheres converge at the Inter-Tropical Convergence Zone (ITCZ). When the ITCZ is farthest from the equator, there must be a temperature contrast between the air masses from each hemisphere.
- This temperature difference between the air masses creates instability, which is a crucial factor for the development and intensification of powerful tropical storms.

Upper Air Disturbance

- An upper air disturbance occurs when the remnants of an upper tropospheric cyclone from the Westerlies move deep into tropical latitudes. This happens because divergence, or the process of air moving apart, is predominant on the eastern side of the troughs, causing air to rise and leading to the formation of thunderstorms.
- These old, abandoned troughs, which are the remnants of temperate cyclones, typically have cold cores. This means that the rate at which temperature decreases with altitude (also known as the environmental lapse rate) is steeper and more unstable beneath these troughs. This instability promotes the development of thunderstorms, which can be referred to as "child cyclones."



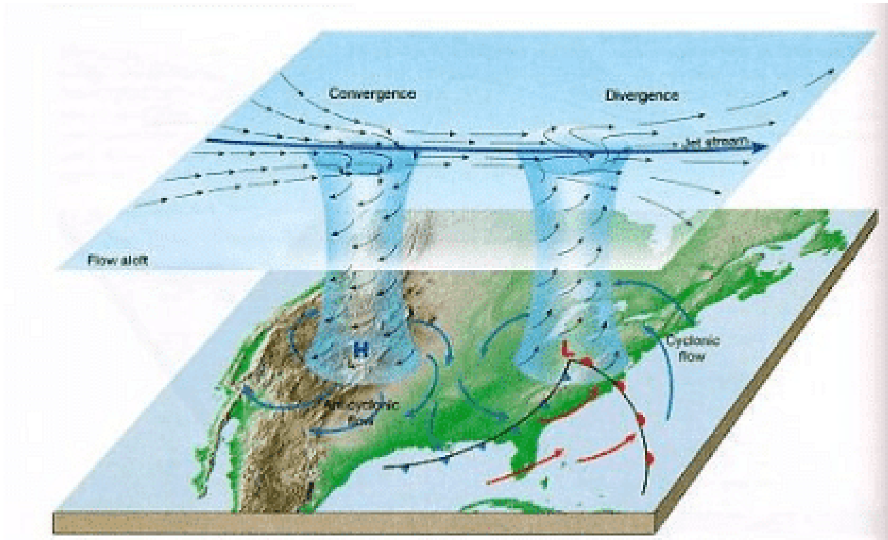
What are the primary ingredients required for the formation of tornadoes? A. Wind shear, lift, instability, and moisture **B.** Warm ocean waters, Coriolis effect, and low wind shear **C.** High wind shear, low pressure, and warm air **D.** Cold fronts, warm fronts, and occluded fronts

Wind Shear

- Wind shear refers to the variations in wind speeds at different altitudes. It plays a significant role in the development of tropical cyclones, which tend to form in areas with uniform wind. When there is weak vertical wind shear, the formation of cyclones is primarily restricted to latitudes closer to the equator, as opposed to the subtropical jet stream regions.
- In contrast, temperate regions experience high wind shear due to the presence of westerly winds. This high wind shear makes it difficult for convective cyclones to form in these areas.

Upper Tropospheric Divergence

- A well – developed divergence in the upper layers of the atmosphere is necessary so that the rising air currents within the cyclone continue to be pumped out and a low pressure maintained at the center.

- 

Humidity Factor

- A high level of humidity, typically between 50 to 60 percent, is necessary in the middle layer of the atmosphere for the formation of cumulonimbus clouds. These conditions can be found in the equatorial doldrums, particularly along the western edges of oceans. This is due to the movement of ocean currents from east to west, which results in a higher moisture-carrying capacity.
- The trade winds also play a role in this process, as they continuously replace the saturated air in these regions.

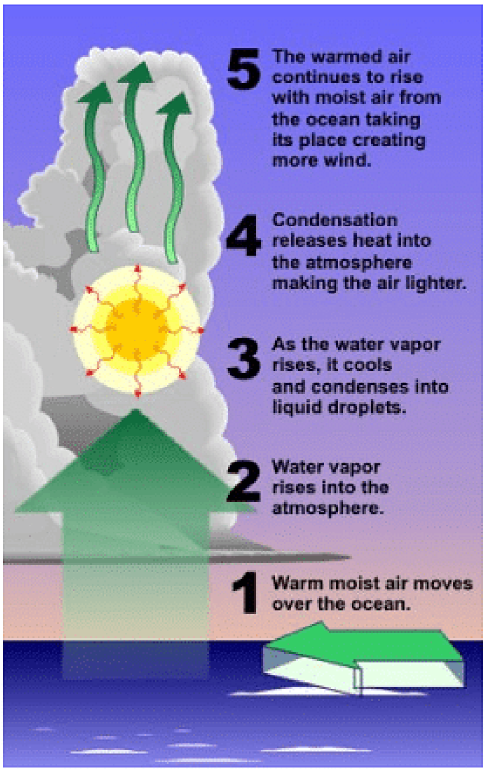
Origin and Development of Tropical Cyclones

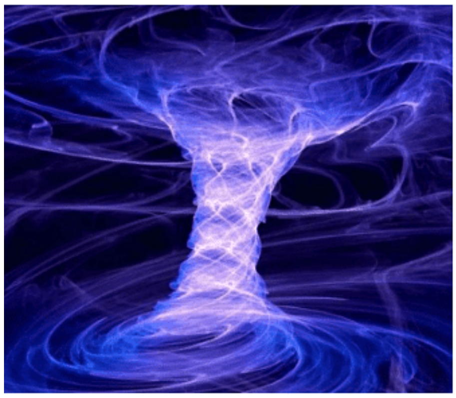
- Tropical cyclones are born from heat and develop over tropical seas during the late summer months, typically from August to mid-November. At these times and locations, powerful local convection currents form, which gain a spinning motion due to the influence of the Coriolis effect.
- Once formed, these cyclones travel until they encounter a weak point in the trade wind belt, where they can continue to develop and strengthen.

Origin

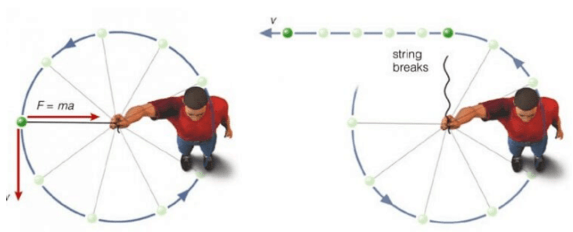
- Under favorable conditions, multiple thunderstorms originate over the oceans. These thunderstorms merge

and create an intense low pressure system (wind is warm and lighter).



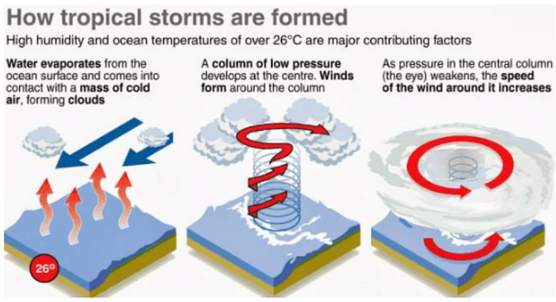


- Due to centripetal acceleration (centripetal force pulling towards the center is countered by an opposing force called the centrifugal force), the air in the vortex is forced to form a region of calmness called an eye at the center of the cyclone. The inner surface of the vortex forms the **eyewall,** the **most violent region** of the cyclone.

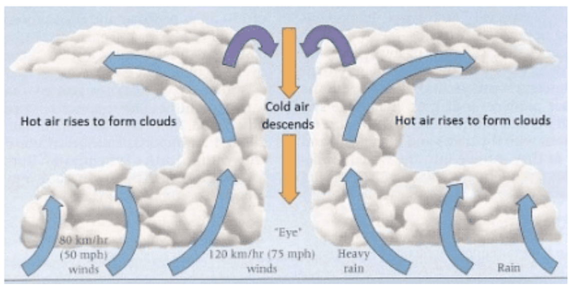


Early stage

- In the early stage of a thunderstorm, warm and light air rises into the atmosphere. As it reaches a certain altitude, the air temperature drops due to the lapse rate and adiabatic lapse rate, causing the moisture in the air to condense. This condensation process releases latent heat, which in turn warms the air even more, making it lighter and causing it to rise further.
- As this cycle continues, fresh moisture-laden air fills the space and also undergoes condensation, as long as there is a sufficient supply of moisture. Over oceans, where there is an excess of moisture, the thunderstorm intensifies and draws in surrounding air at a faster rate. This incoming air is deflected by the Coriolis force, which creates a cyclonic vortex – a spiraling column of air, similar to a tornado. This process continues and the storm grows, fueled by the ongoing supply of moisture and heat.



[Eye is created due to tangential force acting on wind that is following a curvy path]



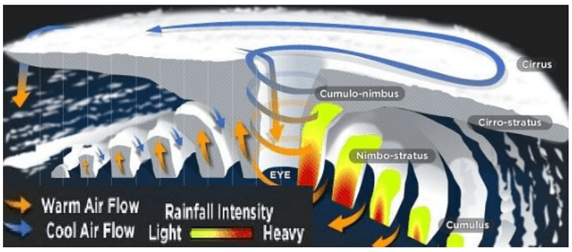
warm Ocean

- All the wind that is carried upwards loses its moisture and becomes cold and dense. It descends to the surface through the cylindrical eye region and at the edges of the cyclone.

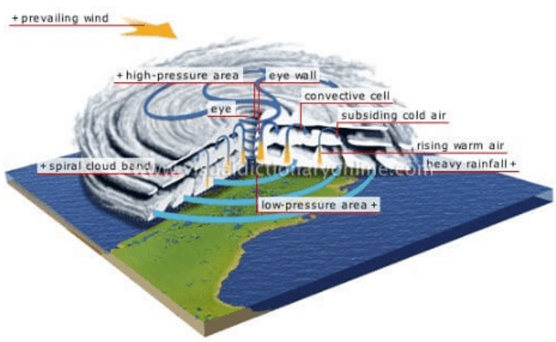
- Continuous supply of **moisture** from the sea is the major driving force behind every cyclone. On reaching the land the **moisture supply is cut off** and the storm dissipates.
- If ocean can supply more moisture, the storm will reach a mature stage.

Mature stage

- During the mature stage of a cyclone, the swirling winds create multiple convective cells, resulting in alternating regions of calm and violent weather. In areas with cumulonimbus cloud formation, known as rain bands, intense rainfall occurs due to the rising air within these convective cells. Eventually, the ascending air loses moisture and descends back to the surface through the calm regions that exist between two rain bands.
- Cloud formation is densest at the center of the cyclone, with the size of the clouds decreasing as they move away from the center. Rain bands are primarily composed of cumulonimbus clouds, while the outer edges of the cyclone contain nimbostratus and cumulus clouds.
- At the upper levels of the troposphere, the central dense overcast is made up of cirrus clouds, which consist mostly of hexagonal ice crystals. Dry air flows along the central dense overcast and descends at the periphery and within the eye region of the cyclone.



Structure of a tropical cyclone



Eye

- The eye of a mature tropical cyclone is a distinct feature characterized by a circular area of relatively calm winds, clear skies, and mild weather situated at the storm's center. This region has minimal precipitation, and sometimes even blue skies or stars can be visible.
- The eye of a tropical cyclone also has the lowest surface pressure and the warmest temperatures in the upper atmosphere, with temperatures at an altitude of 12 km potentially being 10°C warmer or more than the surrounding environment. However, at the surface, the temperature difference is much smaller, ranging between 0-2°C.
- The size of a cyclone's eye can vary greatly, with diameters ranging from 8 km to over 200 km. However, most eyes are typically about 30-60 km in diameter.

Eye wall

- The eye of a tropical cyclone is encircled by the "eyewall," a roughly circular ring of deep convection where the highest surface winds and maximum sustained winds of the cyclone can be found. The eyewall experiences an overall upward flow due to the presence of moderately strong to occasionally intense convection.
- The eye itself contains air that is slowly sinking, leading to warmer temperatures within the eye due to the compressional warming (adiabatic) of the descending air. Most observations taken within the eye reveal a moist lower layer with an inversion above, indicating that the sinking air typically does not reach the ocean surface but stops at around 1-3 km above it.
- The eyewall region not only has the fastest winds in a cyclone but also experiences torrential rainfall. Additionally, rainbands may extend outward from the eyewall, with cumulus and cumulonimbus clouds drifting into the outer areas of the cyclone.

Spiral bands

- Tropical cyclones possess a unique feature called spiral bands, which contribute to the formation and maintenance of the storm's eye. These long, narrow rain bands are organized in a way that aligns with the horizontal wind direction, creating a spiraling appearance as they move towards the center of the cyclone.
- The spiral bands are characterized by strong convection, leading to low-level convergence and upper-level divergence. This creates a circulation pattern where warm, moist air converges at the surface and rises through the bands, diverging at higher altitudes before descending on both sides of the bands.

- The descending air undergoes adiabatic warming and dries out. This subsidence is more concentrated on the inner side of the band, causing a more significant warming effect and a sharp pressure drop across the band as the warmer air is lighter than the colder air. This pressure difference results in an increased pressure gradient, leading to stronger tangential winds surrounding the tropical cyclone.
- Over time, the spiral band moves towards the center of the cyclone and encircles it, giving rise to the formation of the eye and the eyewall. The clear, cloud-free eye may be the result of both dynamic forces that push mass from the eye into the eyewall and the forced downward movement caused by the moist convection in the eyewall.

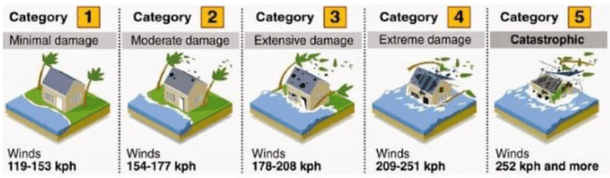
Vertical Structure of a Tropical Cyclone

- The first section, known as the inflow layer, extends up to 3 km in altitude and is responsible for fueling the storm. Air flows into this layer and supplies the storm with the necessary energy to sustain itself.
- The second section, the middle layer, ranges from 3 km to 7 km in altitude, and is where the primary cyclonic activity occurs. This is where the storm's powerful winds, rainfall, and other weather phenomena are generated.
- The third section, the outflow layer, is located above 7 km in altitude. The maximum outflow takes place at 12 km and higher, with air moving in an anticyclonic manner, or opposite to the direction of the rotation of the Earth. This layer helps to release heat and moisture from the storm and contributes to its overall circulation.
- Overall, the vertical structure of a tropical cyclone is a complex system composed of different layers, each playing a crucial role in the development, maintenance, and dissipation of the storm.

Categories of Tropical Cyclones

The tropical cyclone category system, as utilized by the Bureau of Meteorology, classifies cyclones into five categories based on the strength of their winds:

- Category one (tropical cyclone): This type of cyclone has gale-force winds with gusts typically ranging from 90 to 125 kph over open, flat land.
- Category two (tropical cyclone): A category two cyclone features destructive winds with gusts typically ranging from 125 to 164 kph over open, flat land.
- Category three (severe tropical cyclone): This category includes cyclones with very destructive winds, with gusts typically ranging from 165 to 224 kph over open, flat land.
- Category four (severe tropical cyclone): A category four cyclone also has very destructive winds, but with gusts typically ranging from 225 to 279 kph over open, flat land.
- Category five (severe tropical cyclone): The most severe type of cyclone, category five cyclones have extremely destructive winds with gusts typically exceeding 280 kph over open, flat land.



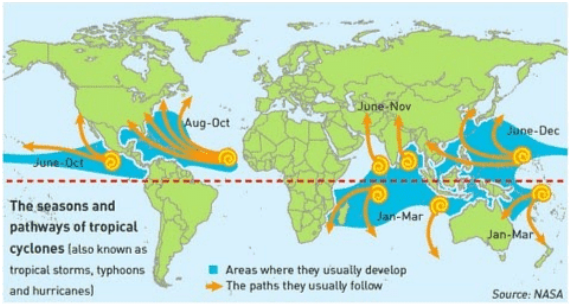
Cyclone Category	Wind Speed in Km/h	Damage Capacity
01	120-150	Minimal
02	150-180	Moderate
03	180-210	Extensive
04	210-250	Extreme
05	250 +	Catastrophic

Type of Disturbances	Wind Speed in Km/h
Low Pressure	Less than 31
Depression	31-49
Deep Depression	49-61
Cyclonic Storm	61-88
Severe Cyclonic Storm	88-117
Very Severe Cyclone	118-221
Super Cyclone	More than 221

Category	Australian name	US*	NW Pacific	Arabian Sea /Bay of Bengal
-	Tropical low	Tropical depression	Tropical depression	Depression or severe depression
1	Tropical cyclone	Tropical storm	Tropical storm	Cyclonic storm
2	Tropical cyclone	Tropical storm	Severe tropical storm	Severe cyclonic storm
3	Severe tropical Cyclone	Hurricane	Typhoon	Very severe cyclonic storm
4	Severe tropical cyclone	Hurricane	Typhoon	Very severe cyclonic storm
5	Severe tropical cyclone	Hurricane	Typhoon	Super cyclonic storm

Favorite Breeding Grounds for Tropical Cyclones

- South-east Caribbean region where they are called hurricanes.
- Philippines islands, eastern China, and Japan where they are called typhoons.
- The Bay of Bengal and the Arabian Sea where they are called cyclones.
- Around the south-east African coast and Madagascar-Mauritius islands.
- North-west Australia.



Regional names for Tropical Cyclones

Regions	What they are called
Indian Ocean	Cyclones
Atlantic	Hurricanes
Western Pacific and South China Sea	Typhoons
Western Australia	Willy-willies

Characteristics of Tropical Cyclones

Tropical cyclones have several distinct features, which are described below.

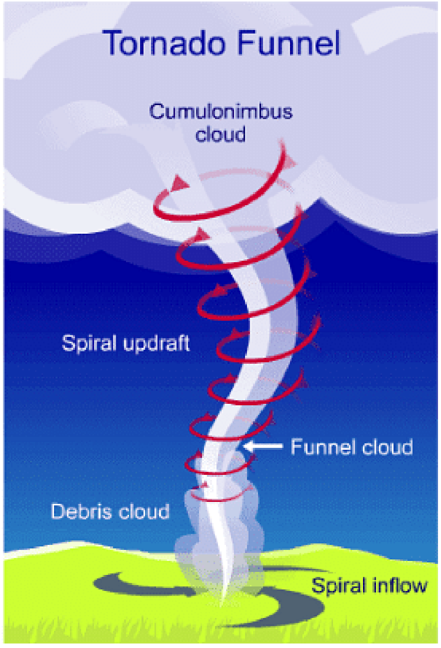
1. **Size and Shape:** These cyclones are typically elliptical, with a 2:3 ratio of length to width, and have steep pressure gradients. They are relatively compact, with a size of about 80 km near the center, but can expand to anywhere between 300 km and 1500 km.
2. **Wind Velocity and Strength:** The wind speed within a tropical cyclone is greater near the poles than at the center, and is higher over oceans than over landmasses, which have physical barriers. The wind velocity can range from zero to 1200 km per hour.
3. **Path of Tropical Cyclones:** Tropical cyclones initially move westward, but turn northward around 20° latitude. They then turn further northeastward around 25° latitude, and finally eastward around 30° latitude, where they lose energy and dissipate. Their paths follow a parabolic shape, with their axes parallel to isobars. Factors such as the Coriolis force, easterly and westerly winds, and Earth's rotation influence the path of tropical cyclones. These cyclones dissipate at 30° latitude due to cooler ocean waters and increasing wind shear caused by westerly winds.
4. **Warning of Tropical Cyclones:** To detect potential cyclones, weather stations monitor changes in pressure, wind velocity, and the storm's direction and movement. There are weather stations located

Major Differences between Temperate Cyclone and Tropical Cyclone

Tropical Cyclone	Temperate Cyclone
Tropical cyclones, move from east to west.	These cyclones move from west to east
A tropical cyclone has an effect on a comparatively smaller area than a Temperate cyclone.	Temperate cyclone affect a much larger area
The velocity of wind in a tropical cyclone is much higher and it is more damaging.	The velocity of air is comparatively lower
Tropical Cyclone forms only on seas with temperature more than 26-27 degree C and dissipate on reaching the land.	Temperate cyclones can be formed on both land and sea
A tropical cyclone doesn't last for more than 7 days	Temperate cyclone can last for a duration of 15 to 20 days

Tornado

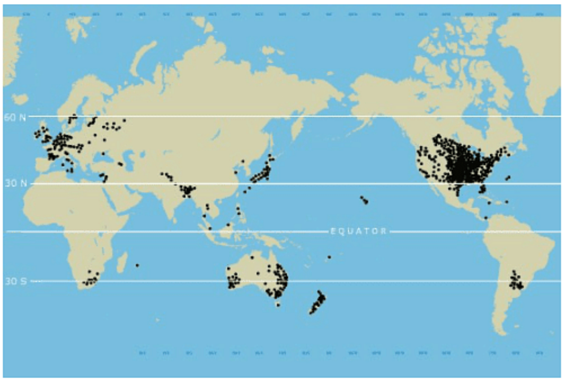
A tornado can be described as an intensely spinning column of air that reaches from a thunderstorm all the way down to the earth's surface. It essentially functions as a whirlwind of high-speed air. The formation of a tornado occurs when alterations in wind velocity and direction generate a horizontal spinning motion within a storm cell. This spinning motion is subsequently turned vertical by the upward movement of air through the thunderclouds.



- Tornadoes are powerful weather events characterized by their high-velocity winds, which can exceed 500 km/h (310 mph). The majority of the damage caused by tornadoes is due to these strong winds. Additionally, tornadoes can cause damage through significant air pressure reductions at their center, which is about 800 millibars, compared to the average sea-level pressure of 1013 millibars. This pressure difference can cause many human-made structures to collapse outward.
- The formation of tornadoes typically requires four primary ingredients: wind shear, lift, instability, and moisture. Wind shear, which is the change in wind speed or direction with altitude, plays the most crucial role in creating tornadoes. This phenomenon can cause winds to form a horizontal column of air. When a strong updraft, or rising air, transports this air from the ground to the atmosphere, the column becomes vertical, often leading to the development of a storm.
- In many cases, the storm evolves into a supercell thunderstorm, which is a discrete, individual storm cell that is not part of a larger line of storms. Supercell thunderstorms are characterized by their rotation and spinning motion. The combination of a vertical, rotating column of air and a supercell thunderstorm can result in the formation of a tornado descending from the storm cloud.
- Tornadoes are most commonly observed during the spring, with a decrease in frequency during the winter months. Spring and fall experience peaks in tornado activity due to the presence of stronger winds, increased wind shear, and greater atmospheric instability. The occurrence of tornadoes is also highly dependent on the time of day, as solar heating plays a significant role in their formation.

Distribution of tornadoes

- Tornadoes are rare in polar regions and are infrequent at latitudes higher than 50° N and 50° S. They are more likely to occur in temperate and tropical regions, where thunderstorms are more common. Tornadoes have been reported on every continent except Antarctica.
- The United States experiences the highest number of violent tornadoes, followed by Canada, which reports the second-highest number of tornadoes overall. In the Indian subcontinent, Bangladesh is the country most susceptible to tornadoes. At any given time, there are approximately 1,800 thunderstorms happening around the world, which contribute to the formation of tornadoes in the most prone areas.



Differences between Tornado and cyclone

	Tornado	Cyclone
Definition	A tornado is a rotating column of air ranging in width from a few yards to more than a mile and whirling at destructively high speeds, usually accompanied by a funnel-shaped downward extension of a cumulonimbus cloud. Winds 40-300+ mph.	A cyclone is an atmospheric system of rapidly circulating air massed about a low-pressure centre, usually accompanied by stormy often destructive weather. Storms that begin in the Southern Pacific are called cyclones
Rotation	Clockwise in the southern hemisphere and counter clockwise in the northern hemisphere	Clockwise in the southern hemisphere and counter clockwise in the northern hemisphere.
Forms of precipitation	rain	Rain, sleet, and hail
Frequency	The United States records about 1200 tornadoes per year, whereas the Netherlands records the highest number of tornadoes per area compared to other countries. Tornadoes occur commonly in spring and the fall season and are less common in winters	10-14 per year
Location	Tornados have been spotted in all continents except Antarctica	Southern Pacific Ocean, Indian Ocean. Cyclones in the northwest Pacific that reach (exceed) 74 mph are "typhoons".
Occurrence	Places where cold and warm fronts converge. Can be just almost anywhere.	warm areas

Tornadoes, as well as cyclones both, occur in India.

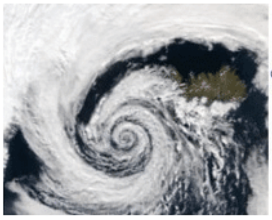
However, unlike cyclones, the frequency of tornado outbreaks is

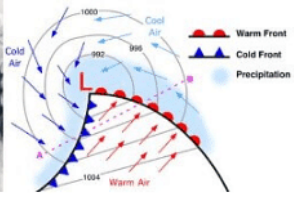
very low. **Cyclones originate in the Bay of Bengal region as well as in the Arabian Sea** region whereas **Tornadoes of weak strength occur in the north-western and north-eastern region** of the country causing significant damage to man and material.

Temperate Cyclone

Temperate cyclones are storm systems that form in the middle and high latitudes, outside of the tropical regions. These low-pressure systems are characterized by the presence of cold fronts, warm fronts, and occluded fronts. They are also known as extra-tropical cyclones, mid-latitude cyclones, frontal cyclones, or wave cyclones. These weather systems develop between 35° and 65° latitude in both the Northern and Southern hemispheres, beyond the tropical zones.

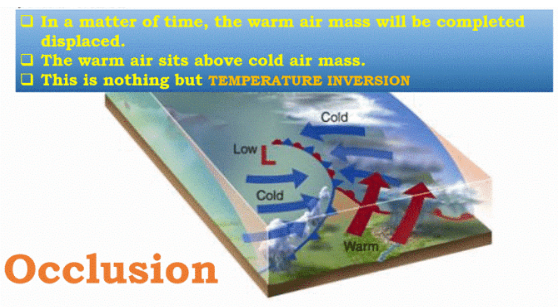
Origin and Development of Temperate Cyclones





Polar Front Theory

- The Polar Front Theory explains the formation of extratropical cyclones, which occur when warm, humid air masses from the tropics meet cold, dry air masses from the poles. This interaction creates a polar front, a boundary where the two air masses meet. This typically occurs over subtropical high and subpolar low-pressure belts, as well as along the tropopause.
- As the cold air pushes the warm air upwards, a void is created due to the decrease in pressure. The surrounding air rushes in to fill this void, and the Earth's rotation causes a cyclone to form, which moves with the westerlies, or jet streams.



- In the Northern Hemisphere, warm air blows from the south, and cold air blows from the north of the polar front. When the pressure drops along the front, the warm air moves northward, and the cold air moves southward, creating an anticlockwise cyclonic circulation due to the Coriolis Force.
- This cyclonic circulation leads to the formation of a well-developed extratropical cyclone, which has both a warm front and a cold front. There are pockets of warm air, or warm sectors, wedged between the forward cold air and the rear cold air, or cold sectors. The warm air glides over the cold air, resulting in a sequence of clouds appearing in the sky ahead of the warm front, causing precipitation.
- The cold front approaches the warm air from behind, pushing the warm air upwards and leading to the development of cumulus clouds along the cold front. Since the cold front moves faster than the warm front, it eventually overtakes it, lifting the warm air completely and resulting in an occluded front. The cyclone then dissipates.
- The wind circulation processes at both the surface and aloft are closely interconnected, making the temperate cyclone a complex system primarily involving occlusion-type fronts. Typically, individual frontal cyclones last for about 3 to 10 days and move in a generally west-to-east direction. The exact movement of these weather systems is determined by the orientation of the polar jet stream in the upper troposphere.

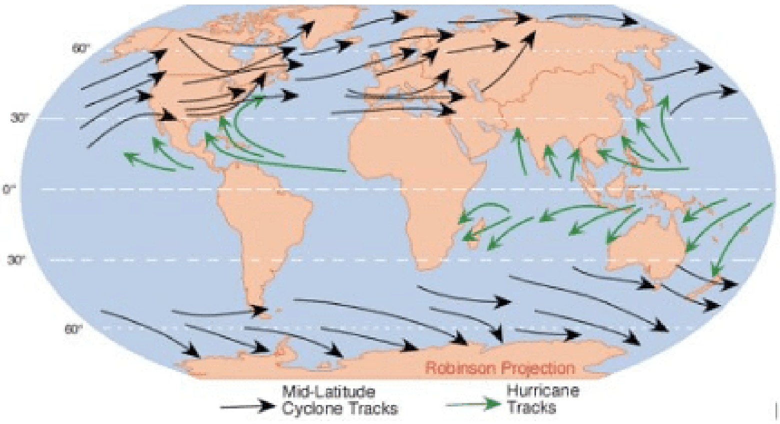
Seasonal Occurrence of Temperate Cyclones

- The temperate cyclones occur mostly in winter, late autumn and spring. They are generally associated with rainstorms and cloudy weather.
- During summer, all the paths of temperate cyclones shift northwards and there are only few temperate cyclone over sub-tropics and the warm temperate zone, although a high concentration of storms occurs over Bering Strait, USA and Russian Arctic and sub-Arctic zone.

Distribution of Temperate Cyclones

- USA and Canada – extend over Sierra Nevada, Colorado, Eastern Canadian Rockies and the Great Lakes region,
- the belt extending from Iceland to Barents Sea and continuing over Russia and Siberia,
- winter storms over Baltic Sea,
- Mediterranean basin extending up to Russia and even up to India in winters (called western disturbances) and the

Antarctic frontal zone.

- 

Characteristics of Temperate Cyclones

Size and Shape

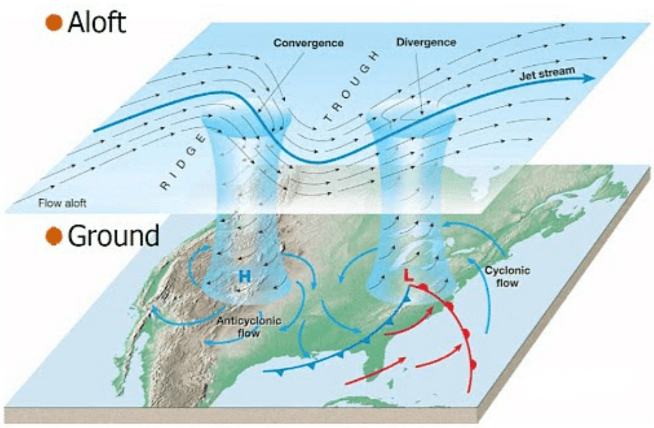
- The temperate cyclones are asymmetrical and shaped like an inverted 'V'.
- They stretch over 500 to 600 km.
- They may spread over 2500 km over North America (Polar Vortex).
- They have a height of 8 to 11 km.

Wind Velocity And Strength

- The wind strength is more in eastern and southern portions, more over North America compared to Europe.
- The wind velocity increases with the approach but decreases after the cyclone has passed.

Orientation And Movement

- Jet stream plays a major role in temperate cyclonogeneis.
- Jet streams also influence the path of temperate cyclones.

- 

- Since these cyclones move with the westerlies (Jet Streams), they are oriented eastwest.
- If the storm front is east-west, the center moves swiftly eastwards.
- If the storm front is directed northwards, the center moves towards the north, but after two or three days, the pressure difference declines and the cyclone dissipates.
- In case the storm front is directed southwards, the center moves quite deep southwards-even up to the Mediterranean region [sometimes causing the Mediterranean cyclones or Western Disturbances (They are very important as they bring rains to North-West India – Punjab, Haryana)].

Structure

- The north-western sector is the cold sector and the north-eastern sector is the warm sector (Because cold air masses in north and warm air masses in south push against each other and rotate anti-clockwise in northern hemisphere).

Associated Weather

- The onset of a temperate cyclone is characterized by a drop in temperature, a decrease in the mercury level, shifting winds, and the appearance of a halo around the sun and moon, as well as a thin layer of cirrus clouds. A light drizzle begins, eventually turning into a heavy downpour. However, these conditions change with the arrival of the warm front, which stops the mercury level from falling and causes the temperature to rise.
- At this point, the rainfall ceases and the weather clears up until the cold front with an anticyclonic nature comes in. This front leads to a drop in temperature, increased cloudiness, and rainfall accompanied by thunder. After this, clear weather returns once more.
- Temperate cyclones typically produce more rainfall when they move slowly and have a significant difference in rainfall and temperature between the front and rear of the cyclone. These cyclones are often accompanied by anticyclones.

What is the main difference between tropical cyclones and temperate cyclones in terms of their formation? A. Tropical cyclones form over warm ocean waters, while temperate cyclones form in the middle and high latitudes **B.** Tropical cyclones are smaller in size compared to temperate cyclones **C.** Tropical cyclones have weaker winds than temperate cyclones **D.** Tropical cyclones occur only in the Northern Hemisphere, while temperate cyclones occur in both hemispheres

Conclusion

Tropical and temperate cyclones are powerful and complex weather systems that form in different regions and under varying conditions. Tropical cyclones develop over warm ocean waters in the tropical regions and are fueled by latent heat, while temperate cyclones form in the middle and high latitudes through the interaction of cold and warm air masses. Both types of cyclones can cause significant damage and impact human life and infrastructure. Tornadoes, although less frequent, are also intense and destructive weather events that result from specific atmospheric conditions. Understanding the formation, development, and characteristics of these weather phenomena is crucial for accurate forecasting and effective disaster preparedness.

What is the main difference between tropical cyclones and temperate cyclones?

The main difference between tropical and temperate cyclones is their location and formation process. Tropical cyclones form in tropical regions over warm ocean waters and are characterized by a warm core and closed air circulation around a low-pressure center. Temperate cyclones, on the other hand, form in middle and high latitude regions and involve interactions between cold and warm air masses, leading to the formation of fronts.

What are the favorable conditions for tropical cyclone formation?

Favorable conditions for tropical cyclone formation include warm ocean waters with a temperature of at least 27°C, sufficient Coriolis effect, minimal vertical wind shear, an existing disturbance or low-pressure system, and favorable upper-level atmospheric conditions, such as upper-level divergence.

Why are tropical cyclones more common in the western tropical oceans?

Tropical cyclones are more common in the western tropical oceans due to the presence of warm ocean currents that flow from east to west, pushed by easterly trade winds. These currents form a thick layer of water with temperatures greater than 27°C, providing sufficient moisture for storm formation. In contrast, cold currents in the eastern parts of the tropical oceans reduce surface temperatures, making these regions unsuitable for cyclonic storm development.

What are the various names for tropical cyclones in different regions of the world?

Tropical cyclones have different names depending on where they develop in the world. They are known as hurricanes in the Atlantic and eastern Pacific, typhoons in the western Pacific, and cyclones in the Indian Ocean and the South Pacific.

How can people prepare for and protect themselves from tropical cyclones?

To prepare for tropical cyclones, people should stay informed about weather forecasts and warnings, develop an emergency plan, and assemble an emergency supplies kit. During a tropical cyclone, individuals should stay indoors, away from windows and glass doors, and follow instructions from local authorities. After the cyclone has passed, it is essential to exercise caution when returning home or venturing outside, as there may be damage and hazards present.

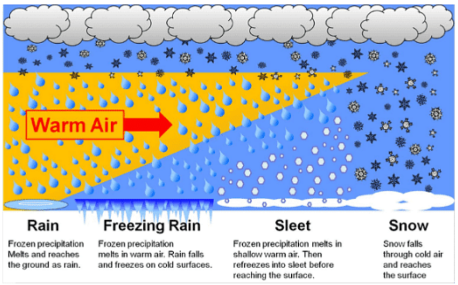
Types & Distribution of Precipitation

What is precipitation?

Precipitation refers to the various forms of water particles, either in liquid or solid state, that fall from the atmosphere and make contact with the Earth's surface. This encompasses various weather phenomena such as drizzle, rain, hail, snow, and sleet.

Types of Precipitation

- Rain
- Drizzle
- Snow
- Sleet
- Hail



Rain

- Rain consists of liquid droplets that fall from the sky. As these droplets descend from high-altitude clouds, some of them evaporate when they pass through layers of dry air. In certain instances, the raindrops evaporate entirely before they reach the ground, resulting in a phenomenon known as virga. In contrast, when there is a thick layer of clouds and the lower atmosphere is moist, heavy rainfall occurs. In this type of precipitation, the raindrops are larger and more numerous, making it the more common form of rainfall.
- Raindrops are liquid particles that fall from the atmosphere to the surface, with a diameter of more than 0.5 millimeters. The maximum size of a raindrop is typically around 5 to 7 millimeters, as larger drops cannot remain suspended in the air. When raindrops become too big, the intermolecular cohesive forces are not strong enough to hold the water mass together as a single drop.

Drizzle

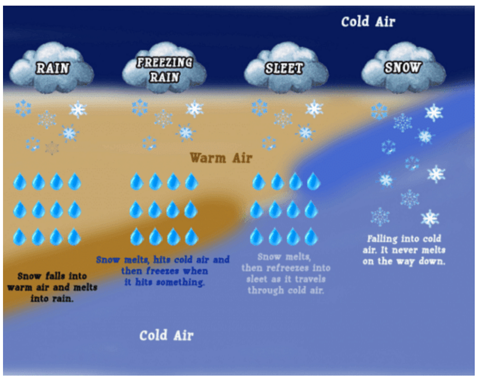
Drizzle refers to a type of light rainfall characterized by its small, uniformly-sized droplets that appear to gently float in the air. These droplets typically have a radius of less than 500 microns or a size less than 0.5 mm. This type of precipitation often occurs when the relative humidity between the cloud base and the ground is nearly 100%, creating a moist environment for the tiny droplets to form and persist.

Which type of rainfall occurs when warm, moist air traveling over the ocean encounters large mountain ranges, forcing the air to rise? A. Convectional rainfall **B.** Orographic rainfall **C.** Cyclonic rainfall **D.** Monsoonal rainfall

Drizzle

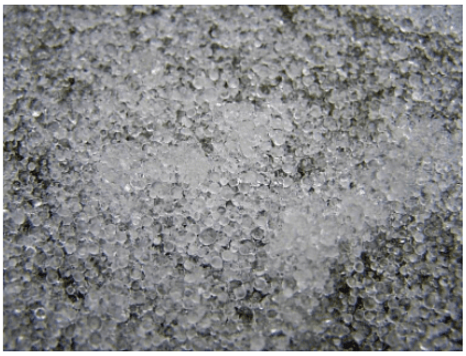
Snow

Snow is a type of precipitation that consists of white, opaque crystals. It forms when the temperature in cloud formations is below 0 degrees Celsius, which is commonly found in middle and high latitudes. Snow develops as a result of water vapor turning directly into a solid crystal, with a hexagonal (six-sided) structure, when the temperature is below freezing.



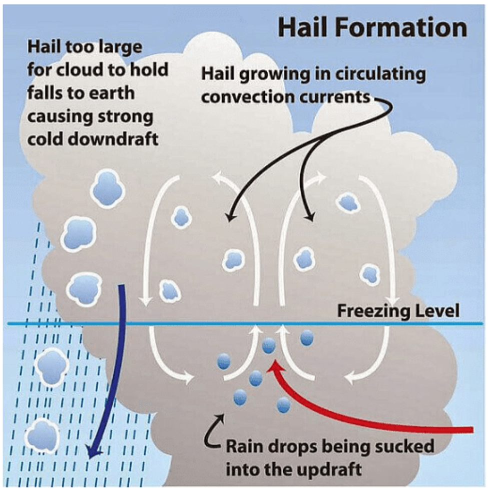
Sleet

Sleet is a form of precipitation that consists of a combination of rain and snow. This occurs when raindrops, as they fall to the ground, pass through a layer of extremely cold air. As a result, the rain partially freezes, creating a mixture of rain and snow. In some cases, sleet can develop into hailstorms if there are strong vertical air currents present in the atmosphere. When this happens, the frozen rain can grow in size, with a diameter of more than 5 millimeters.



Hail

Hail is a type of precipitation that occurs during severe thunderstorms or within cumulonimbus clouds. It consists of small ice pellets, which can cause significant damage due to their size and density. These ice pellets have a layered structure, similar to an onion, with alternating layers of ice and snow. Hailstones typically have a diameter of more than 5 mm, making them the most destructive form of precipitation.



Rainfall

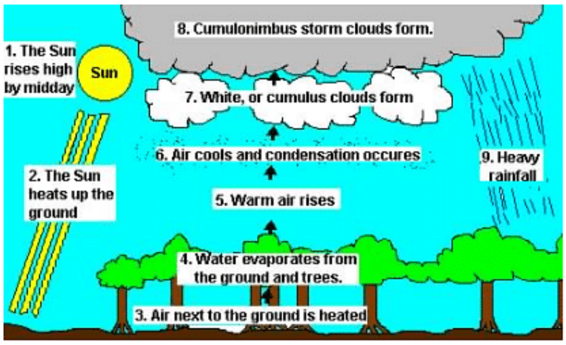
Rainfall can be defined as the precipitation in the liquid form. There are various types of rainfall based on the origin

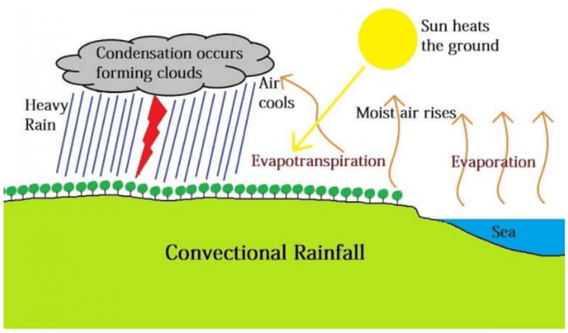
Types of Rainfall

On the basis of mode of occurrence, the rainfall can be classified into three categories: – the convectional, orographic, or relief and the cyclonic or frontal.

Convectional rainfall

- Convectional rainfall occurs when the Earth's surface is heated, causing the air above it to warm up. This warming causes the air molecules to spread out, making the air less dense and allowing it to rise rapidly into the atmosphere. As this warm air rises, it cools down, and the water vapor within it condenses to form clouds and eventually precipitation.
- This type of rainfall is commonly found in areas with intense heat and high levels of moisture, such as the equatorial regions and the doldrums belt. The primary source of heat driving these convectional currents is solar radiation from the sun.
- However, convectional rainfall is not highly beneficial for agriculture, as much of the water quickly drains off the land as surface runoff, leaving minimal moisture for crops to absorb.



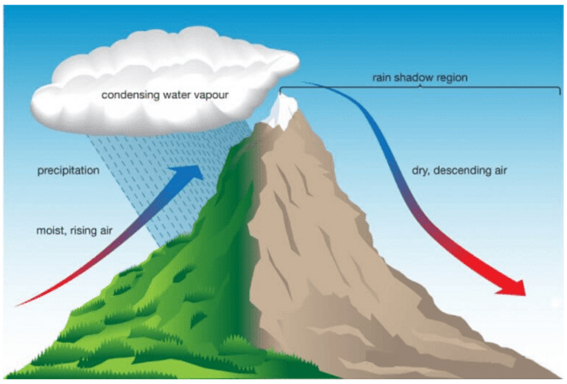


Orographic rainfall

- Orographic rainfall occurs when warm, moist air traveling over the ocean encounters large mountain ranges, forcing the air to rise. As the air ascends, it cools down,

causing the water vapor within it to condense and form water droplets.

- This leads to the formation of clouds and ultimately precipitation, either as rain or snow, on the windward side of the mountain range. The amount of rainfall tends to decrease at higher elevations on the windward side.
- Once the now-dry air rises above the mountain, it begins to descend on the other side, known as the leeward side. During this descent, the air absorbs moisture from the ground through evaporation. However, the leeward side receives very little precipitation in comparison to the windward side due to the dryness of the air.



What is the main difference between fog and clouds?

A. Fog is a ground-level cloud, while clouds are not at ground level.

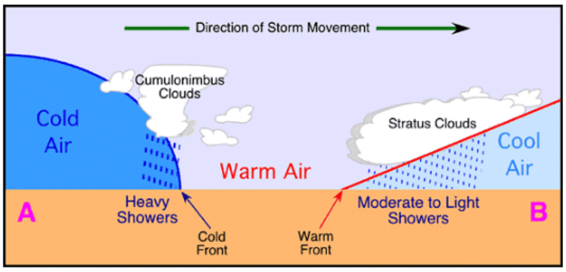
B. Fog consists of water droplets, while clouds consist of ice crystals.

C. Fog only occurs over land, while clouds can form over both land and water.

D. Fog occurs due to the cooling of rising air, while clouds form when air at the Earth's surface cools below its dew point temperature.

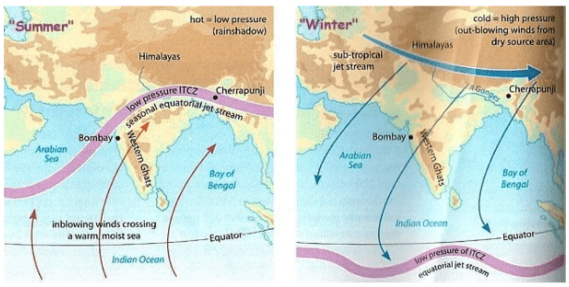
Cyclonic or frontal rainfall

- Cyclonic rainfall occurs when large air masses with distinct temperature and humidity characteristics converge, causing the warmer, moist air to rise above the cooler, drier air. This process is also known as frontal precipitation, as it typically occurs at the boundary between a warm front and a cold front.
- When these two air masses meet, the denser, colder air forces the lighter, warmer air to ascend. As the warm air rises, it experiences adiabatic cooling, which means it cools without losing heat to its surroundings. This cooling causes the water vapor within the air mass to condense, forming clouds and eventually leading to precipitation.
- In summary, cyclonic or frontal rainfall is the result of the interaction between warm, moist air and cool, dry air, leading to the formation of clouds and subsequent precipitation as the warm air is forced to rise and cool.



Monsoonal Rainfall

This type of precipitation is characterized by seasonal reversal of winds that carry oceanic moisture (especially the south-west monsoon) with them and cause extensive rainfall in the south and southeast Asia.



World Distribution of Rainfall

The amount of rainfall varies across the Earth's surface, with different regions receiving different amounts of precipitation throughout the year and in various seasons. Generally, rainfall decreases as one moves from the equator towards the poles. Coastal regions typically receive more rainfall than inland areas, and there is more rainfall over the oceans than on land due to the vast water sources.

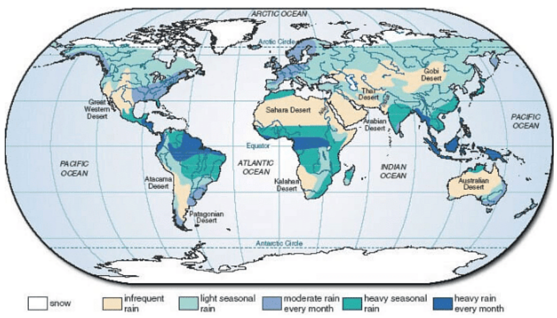
In the latitudes between 35° and 40° North and South of the equator, eastern coasts experience heavier rainfall, which gradually decreases towards the west. Conversely, between 45° and 65° North and South of the equator, westerly winds bring more rainfall to the western margins of continents, with precipitation decreasing towards the east. In regions where mountains run parallel to the

coast, greater rainfall occurs on the coastal plains and windward side, while it decreases towards the leeward side.

Based on the total annual precipitation, the following major precipitation regimes can be identified:

- Heavy rainfall, exceeding 200 cm per year, occurs in the equatorial belt, windward slopes of mountains along the western coasts in cool temperate zones, and coastal areas of monsoon regions.
- Moderate rainfall, ranging from 100 to 200 cm per year, is experienced in the interior continental areas and the coastal regions of continents.
- In central parts of tropical lands and eastern and interior parts of temperate lands, rainfall varies between 50 and 100 cm per year.
- Regions in the rain shadow zones of the interior of continents and high latitudes receive very low rainfall, less than 50 cm per year.

The seasonal distribution of rainfall is also an essential factor in determining its effectiveness. In some areas, such as the equatorial belt and western parts of cool temperate regions, rainfall is evenly distributed throughout the year.



Virga

In meteorology, virga is an observable streak or shaft of precipitation falling from a cloud but evaporates or sublimates before reaching the ground.

Fog

Fog can be described as a ground-level cloud. While there is no physical distinction between clouds and fog, their formation processes differ. Clouds typically form due to the cooling of rising air, while fog formation rarely involves uplift. Fog usually forms when the air at the Earth's surface cools below its dew point temperature, or when sufficient water vapor is added to saturate the air. There are four main types of fog:

- Radiation fog occurs when the ground loses heat through radiation, typically at nighttime. As heat radiates from the ground, it passes through the lowest layer of air and moves into higher regions. The air closest to the ground cools as heat is conducted from it to the cooler ground, causing fog to condense at the dew point, often accumulating in low areas.
- Advection fog develops when warm, moist air moves horizontally over a cold surface, such as snow-covered ground or a cold ocean current. Advection fogs are most commonly formed when air moves from sea to land.
- Upslope fog, also known as orographic fog (from the Greek word "oro" meaning "mountain"), forms due to adiabatic cooling when humid air ascends a topographic slope.
- Evaporation fog occurs when water vapor is added to cold air that is already near saturation.

Dew

Dew is primarily formed due to terrestrial radiation, which occurs during the night. As the Earth's surface releases energy in the form of radiation, objects like grass, pavement, and cars become cool. This cooling effect is then transferred to the surrounding air through a process called conduction. When the air becomes cool enough to reach saturation, small water droplets gather on the cold surface of these objects. In cases where the temperature falls below freezing, ice crystals (also known as white frost) form instead of water droplets.

Conclusion

Precipitation refers to various forms of water particles, such as rain, drizzle, snow, sleet, and hail, that fall from the atmosphere to the Earth's surface. Precipitation occurs through different processes, including convectional, orographic, cyclonic, and monsoonal rainfall. The distribution of rainfall across the globe varies, with some regions receiving heavy rainfall while others experience minimal precipitation. Other related meteorological phenomena include virga, fog, and dew, which occur due to specific atmospheric conditions and processes. Understanding these various types of precipitation and their formation is critical for predicting weather patterns and managing water resources.

What factors affect the amount and distribution of rainfall in different regions?

The amount and distribution of rainfall are influenced by factors such as latitude, coastal or inland location, ocean currents, wind patterns, and the presence of mountains or other topographic features.

What is the difference between drizzle and rain?

Drizzle refers to light rainfall with small, uniformly-sized droplets that appear to gently float in the air, typically with a diameter of less than 0.5 mm. Rain, on the other hand, consists of larger liquid droplets that fall from the sky with a diameter of more than 0.5 millimeters.

Why does orographic rainfall occur more on the windward side of a mountain range?

Orographic rainfall occurs when warm, moist air encounters a mountain range and is forced to rise. As the air ascends, it cools down, causing the water vapor within it to condense and form water droplets, leading to precipitation on the windward side of the mountain range. The leeward side receives less precipitation because the air is drier after losing moisture on the windward side.

What causes convectional rainfall and where is it most commonly found?

Convectional rainfall occurs when the Earth's surface is heated, causing the air above it to warm up and rise rapidly into the atmosphere. As this warm air rises, it cools down, and the water vapor within it condenses to form clouds and eventually precipitation. Convectional rainfall is commonly found in areas with intense heat and high levels of moisture, such as equatorial regions and the doldrums belt.

How does cyclonic or frontal rainfall form?

Cyclonic or frontal rainfall occurs when large air masses with distinct temperature and humidity characteristics converge, causing the warmer, moist air to rise above the cooler, drier air. As the warm air rises, it cools down, causing the water vapor within it to condense and form clouds, which leads to precipitation. This type of rainfall typically occurs at the boundary between a warm front and a cold front.

1. What is precipitation?

Ans. Precipitation refers to any form of water that falls from the atmosphere to the Earth's surface. It includes various forms such as rain, snow, sleet, and hail.

2. How is rainfall measured?

Ans. Rainfall is typically measured using a rain gauge. A rain gauge is a simple instrument that collects and measures the amount of rainfall in a specific area. It consists of a cylindrical container with markings to indicate the amount of rainfall in millimeters or inches.

3. What factors influence the distribution of rainfall around the world?

Ans. The distribution of rainfall is influenced by various factors such as prevailing winds, topography, proximity to large water bodies, and atmospheric conditions. These factors determine the amount and frequency of rainfall in different regions of the world.

4. Which regions of the world receive the highest amount of rainfall?

Ans. The regions that receive the highest amount of rainfall are typically located near the equator or in tropical regions. These areas experience high levels of humidity and are influenced by the convergence of trade winds, leading to abundant rainfall.

5. How does rainfall impact the environment and human activities?

Ans. Rainfall plays a crucial role in sustaining ecosystems and supporting agriculture. Sufficient rainfall is necessary for the growth of crops and plants. It also replenishes water sources such as rivers, lakes, and groundwater. However, excessive rainfall can lead to flooding and landslides, causing damage to infrastructure and property.

Weather & Climate

Climate refers to the long-term patterns and average conditions of various weather elements, such as temperature, humidity, atmospheric pressure, wind, precipitation, and the concentration of particles in the atmosphere, within a specific region.

Studying any of these individual factors alone does not provide a complete understanding of a region's climate. Instead, it is the combination of these elements that create the various types of climates found around the world. Thus, there could potentially be thousands of unique climates based on the various interactions and patterns of these meteorological variables.

Weather & Climate

Weather

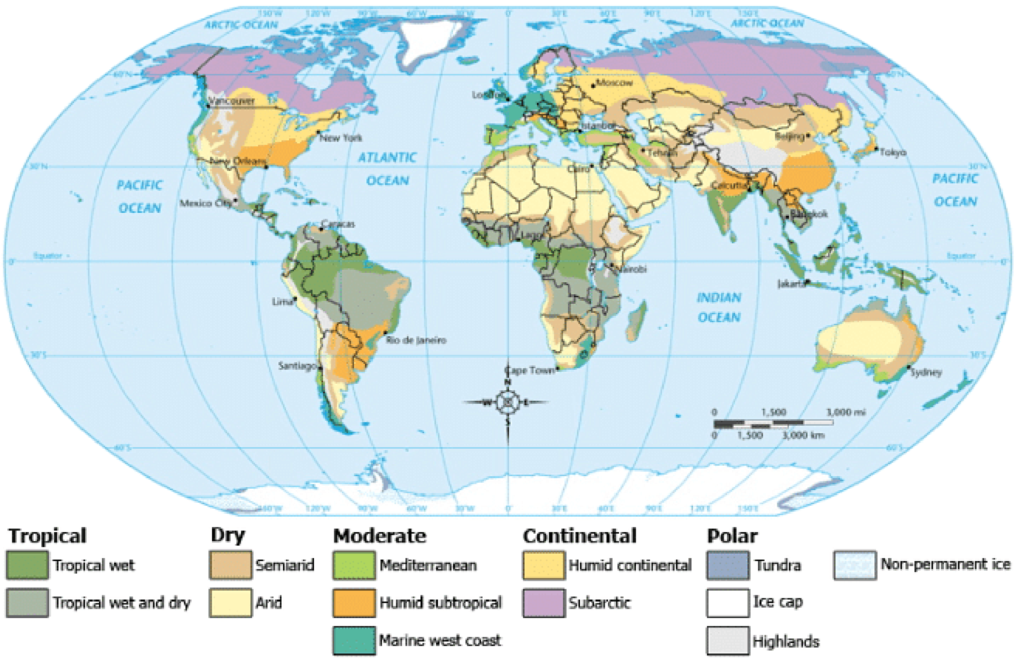
- Weather refers to the short-term state of the atmosphere in a specific location, which includes factors such as temperature, humidity, precipitation, air pressure, wind, and cloud cover. Weather mainly occurs in the troposphere, the lowest region of the atmosphere that extends from Earth's surface up to around 6-8 km at the poles and about 17 km at the equator. This is because the troposphere contains almost all clouds and is where most precipitation forms.
- On the other hand, climate refers to the long-term synthesis of weather conditions that have occurred in a particular area over an extended period, typically 30 years. While weather describes short-term atmospheric phenomena, climate provides an overview of the average weather patterns in a specific region.
- Various factors affect weather, including geographic features such as mountains and large bodies of water like lakes and oceans. Recent research has shown that ocean-surface temperature anomalies can potentially influence atmospheric temperature anomalies in subsequent seasons and distant locations. One example of such an interaction between the ocean and the atmosphere affecting weather is the El Niño/Southern Oscillation (ENSO) phenomenon.

What is the primary difference between weather and climate?

A. Weather refers to short-term atmospheric conditions, while climate refers to long-term weather patterns.
B. Climate refers to short-term atmospheric conditions, while weather refers to long-term weather patterns.
C. Weather only occurs in the troposphere, while climate occurs in all layers of the atmosphere.
D. Climate is only affected by temperature and precipitation, while weather is affected by various factors such as humidity, wind, and atmospheric pressure.

Climate

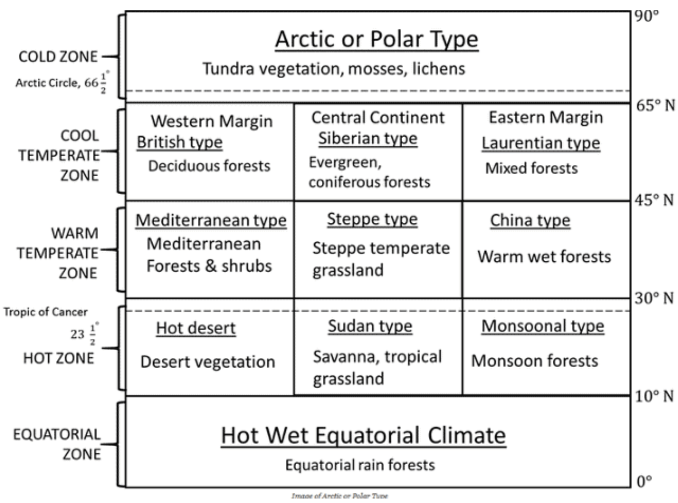
- Climate refers to the long-term atmospheric conditions in a specific location, encompassing the various elements that make up weather patterns over an extended period.
- The primary factors that contribute to climate include sunlight exposure, temperature fluctuations, levels of humidity, different forms of precipitation (such as rain or snow) and their frequency, atmospheric pressure, and wind patterns in terms of speed and direction.
- In short, climate is a comprehensive representation of the weather-related components that persistently occur in a given area over a considerable length of time.



World Climatic Types

Climatic Zone	*Latitude (Approximate)*	*Climatic Type*	*Rainfall Regime (with approx. total)*	*Natural Vegetation*
Equatorial Zone	0°-10°N and S	1. Hot, wet equatorial	Rainfall all year round : 80 inches	Equatorial rain forests
Hot Zone	10°-30°N and S	2. a) Tropical Monsoon b) Tropical Marine 3. Sudan Type 4. Desert: a) Saharan type b) Mid-latitude type	Heavy summer rain: 80 binches Much summer rain: 70 inches Rain mainly in summer: 30 inches Little rain: 5 inches	Monsoon forests Savanna (tropical grassland) Desert vegetation and scrub
Warm Temperate Zone	30-°40°N & S	Western Margin (Mediterranean type) 6. Central Continental (Steppe type) 7. Eastern Margin: a) China type b) Gulf type c) Natal type	Winter rain: 35 inches Light summer rain: 20 inches Heavier summer rain : 20 inches	Mediterranean forests and shrub Steppe or temperate grassland Wawrm, wet forests and bamboo
Cool Temperate Zone	45°-65°N & S	8. Western Margin (British type) 9. Central Continental (Siberian type) 10. Eastern Margin (Laurentian type)	More rain in autumn & winter : 30 inches Light summer rain: 25 inches Moderate summer rain : 40 inches	Decidous forests Evergreen coniferous forests Mixed forests (coniferous and deciduous)
Cold Zone	65°-90° N & S	11. Arctic or Polar	Very light summer rain : 10 inches	Tundra, mosses, lichens
Alpine Zone		12. Mountain climate	Heavy rainfall (variable)	Alpine pastures, confiers, fern, snow

Climatic Regions of World



Hot, Wet Equatorial Climate

Distribution

- 50 North – 100 South from equator
- No impact of trade winds, if you go away from this will have monsoon type climate.
- Basically, hot, wet type of climate but also have cool places like Cameron highland in Malaysia because these places are at high altitude.
- Examples of some Countries: Ecuador, Colombia, Brazil, Peru, Nigeria, Liberia, Myanmar, Thailand, Cambodia, Malaysia, Java

Climate

- There is great uniformity of temperature throughout the year.
- The mean monthly temperatures are always around 24 to 27ºC, with very little variation.
- There is no winter.
- The diurnal and annual range of temperature is small.
- Precipitation is heavy between 6o inches and 10 inches, and well distributed throughout the year.
- The double rainfall peaks, coinciding with the equinoxes are a characteristics feature of it.

Natural Vegetation

- It support a luxuriant type of vegetation – the tropical rain forest.
- Amazon tropical rain forest is known as Selvas.
- It comprises a multitude of evergreen trees that yield tropical hardwood, e.g. mahogany, ebony, greenheart, cabinet wood. And dyewoods.
- Lianas, epiphytic and parasitic plants are also found.
- Trees of single species are very scarce in such vegetation.

Economy

- The equatorial regions are generally sparsely populated.
- In the forests, most primitive people live as hunters and collectors and the more advanced ones practice shifting cultivation.
- Some plantation crops are also practiced like natural rubber, cocoa, etc.

Savanna or Sudan Climate (or Tropical Wet and Dry Climate)

- The Savanna or Sudan climate is a transitional type of climate situated between equatorial forests and trade wind hot deserts. This climate is predominantly found within the tropics, specifically between the Tropic of Cancer and the Tropic of Capricorn.
- It is most prominently developed in Sudan, where the distinction between wet and dry climates is most noticeable, hence the name "Sudan climate."
- This climate type encompasses large portions of Africa (such as Kenya, Nigeria, and Gambia), as well as significant areas in Australia, South America (like the Brazilian highlands), and India.
- The Savanna climate is characterized by a distinct dry season that occurs during the winter months, with the majority of rainfall concentrated in the summer season. The extended dry season leads to the death of many plants and the drying up of streams, which in turn forces animals to migrate in search of water and food.

Distribution

- The Sudan climate is predominantly located within the tropical latitudes, on both sides of the equator, and is characterized by distinct wet and dry seasons. This climate type is named after its well-developed presence in Sudan, Africa.
- In the northern hemisphere, regions with Sudan climate include African Sudan and East Africa, as well as the Llanos grasslands in the Orinoco River basin of South America. In the southern hemisphere, the Sudan climate can be found in the Campos grasslands of the Brazilian Highlands in South America, and in Northern Australia, just south of the monsoonal region.
- Overall, the Sudan climate is typically found in areas close to the equator, spanning across various continents,

with its main feature being the clear wet and dry seasons it experiences.

Temperature

- In the savanna region, monthly temperatures typically range from 20 to 32 degrees Celsius in the lowlands, with variations increasing as one moves further from the equator. The average annual temperature in this area is approximately 18 degrees Celsius. The highest temperatures are usually experienced just before the start of the rainy season, which occurs in April in the northern hemisphere and October in the southern hemisphere. Interestingly, June, when the summer solstice takes place in the northern hemisphere, does not see the highest temperatures.
- During the rainy season, the presence of clouds in the sky causes a decrease in temperature levels. In the hot season, temperatures often surpass 37 degrees Celsius during the day. However, clear skies at night lead to a rapid loss of heat, causing temperatures to drop below 10 degrees Celsius even in the hot season. Night frosts are common during this time.
- One notable characteristic of the savanna climate is the significant difference between daytime and nighttime temperatures, also known as the extreme diurnal temperature range.

Precipitation

- The region's climate is marked by two distinct seasons - a hot and wet season, followed by a cooler, dry period. In the northern hemisphere, the warm, rainy season typically lasts from May to September, as seen in Kano, Nigeria. The remainder of the year is characterized by cooler, dry weather. Situated at an elevation of more than 1500 meters above sea level, Kano experiences over 80 centimeters of rainfall, which primarily occurs during the summer months.
- Conversely, in the southern hemisphere, the wet season takes place from October to March. As one moves further from the equator and closer to desert areas, both the duration of the rainy season and the total annual precipitation decrease significantly.

Winds

- Trade winds are the dominant winds in a region that bring rainfall to coastal areas. These winds generally flow from east to west, resulting in the highest rainfall on the eastern coasts. Trade winds are particularly strong during the summer when the Intertropical Convergence Zone (ITCZ) is positioned over hot deserts. As these winds travel over coastal regions, they lose their moisture, and by the time they reach the interiors of continents, they become relatively dry.
- In West Africa, the easterly trade winds carry dry, dusty air from the Sahara, eventually reaching the coast of Guinea. This hot, dry, and dusty wind is locally known as the Harmattan, which means "the doctor." Although the Harmattan can have a negative impact on crops, it also brings a cooling effect, offering some relief from the humid air of Guinea by increasing evaporation rates.
- The trade winds are responsible for the distinct, alternating dry and wet seasons in the region. During the summer, onshore trade winds carry moisture-laden air, resulting in rainfall. In contrast, during the winter, the winds blow offshore, keeping the weather dry.

Vegetation

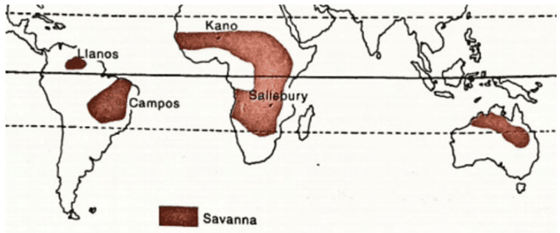
- The vegetation in this region is characterized by tall grasses and short trees, often referred to as 'bush-veld' or 'parkland'. Tree coverage is most dense near the equator and along riverbanks, and it becomes less dense and shorter as you move away from the equator.
- The trees in this region are typically deciduous, meaning they shed their leaves during the dry and cool seasons to minimize water loss through transpiration. Acacia trees are a common example of this type of vegetation. Other tree species have broad trunks that serve as water storage spaces, allowing them to survive dry seasons or droughts. Examples of these trees include baobabs and bottle trees.
- These trees are often hardwood and may have thorns, and they can produce substances such as gum arabic. The grasses in this area are tall and coarse, growing up to 6-12 feet in height. Elephant grass, the tallest variety, can even reach up to 15 feet tall. The grass has a compact structure and long roots that extend deep into the ground in search of water.
- During the dry season, the grass appears dormant, but it comes back to life during the rainy season. As you move closer to the desert, the grasslands gradually transition into thorny scrublands.

Wildlife

- The savanna is home to some of the largest land animals on Earth, which can be divided into two main categories: herbivores and carnivores.
- Well-known herbivores that inhabit the savanna include zebras, giraffes, elephants, and antelopes. These animals possess unique adaptations to help them survive, such as incredible speed for outrunning predators or exceptional camouflage abilities to avoid detection.
- Key carnivores in the savanna ecosystem consist of lions, hyenas, leopards, panthers, pumas, and jaguars. These predators are equipped with strong jaws and sharp teeth, enabling them to effectively attack and consume their prey.
- In addition to these animals, the savanna also hosts various reptiles, such as crocodiles, monitor lizards, and giant lizards, which can be found along rivers and in marshy areas. Rhinoceroses and hippopotamuses are other notable inhabitants of these wetland regions.

Economy

- The economy of this region largely consists of nomadic pastoralism, settled agriculture, and plantation agriculture. Nomadic pastoralists, such as the Masai found in Kenya and Tanzania, rely on their livestock for survival and maintain a traditional way of life. Settled agriculture is practiced by numerous tribes, such as the Hausa, who have domesticated animals to aid in crop cultivation.
- Plantation agriculture, present in areas like northern Australia, eastern Brazil, and central Africa, highlights the substantial agricultural potential of the region. Crops such as cotton, sugarcane, oil palm, groundnuts, coffee, and tropical fruits are commonly grown. Additionally, tribes cultivate small amounts of millets, bananas, and vegetables for their own consumption.
- However, the region faces challenges such as frequent droughts, which threaten crop cultivation, especially during the extended dry seasons. In many areas, heavy rainfall during the wet season leads to the leaching of topsoil and essential nutrients like nitrates, phosphates, and potash, resulting in lateritic soils that are unsuitable for crop cultivation.
- The poor quality of grass in this region does not support large-scale animal ranches typically found in temperate grasslands, resulting in low meat and dairy production. Despite these challenges, some regions have embraced modern science and technology to become leading exporters of meat and dairy products, such as Queensland in Australia.



Tropical Monsoon Climate

- The tropical monsoon climate, also known as the monsoon climate, can be found in the area between the Tropic of Cancer and the Tropic of Capricorn. This region is affected by the movement of the inter-tropical convergence zone (ITCZ) and experiences hot and humid conditions throughout the year due to the sun's consistent overhead position.
- Monsoons are characterized by seasonal winds that blow across land and sea, causing a shift in wind direction and resulting in variations in temperature and precipitation. These seasonal winds are responsible for the three distinct seasons observed in this climate region: summer, winter, and the rainy season.

Distribution

They are confined within 5 – 30 degrees latitudes on either side of the equator.
Indian subcontinent, Indo-China (Laos. Vietnam, Cambodia), Thailand. southern China and northern Australia are the regions experiencing this climate.

- **Winds**
  The seasonal reversal in the direction of winds is an outcome differential rate of heating and cooling of the continental landmasses and seawaters.
- During the summers, a low-pressure region develops over Central Asia as the sun comes overhead the Tropic of Cancer. This causes the Asian landmass to heat up faster than the surrounding seas, which remain at a higher pressure in the northern hemisphere.
- In the southern hemisphere, winter conditions prevail, leading to a high-pressure zone over northern Australia.
- Winds blow outward from the Australian landmass towards Java (Indonesia) and are drawn towards the low-pressure region over the Indian subcontinent after

crossing the equator, under the influence of the Coriolis force. These are the South-West monsoon winds.
- During winters, a reversal in the wind direction occurs.

Temperature

- Owing to the region's proximity to the tropics, it experiences warm to hot summers.
- Average monthly temperature is above 18 degrees centigrade, but in summers the maximum can reach as high as 45 degrees centigrade.
- The average temperature in the summer is around 30 degrees centigrade, with an overall temperature range of 30 to 45 degrees centigrade.
- Winters are mild with a temperature range of 15 to 30 degrees centigrade. Mean temperature during winters is around 25 degrees centigrade.

Precipitation

- The region experiences very high rainfall, which is concentrated in a few months.
- Annual average rainfall is around 200-250 cm. However, some regions have a very high average of around 350 cm.
- In India, Maysynram and Cherrapunji of Khasi Hills (Meghalaya) experience an annual rainfall of over 1000cm. They are located on the windward side of the hills, causing heavy orographic rainfall (caused by a lift of the monsoon winds). Due to the location in between mountains which causes a concentration of rain-bearing clouds, also known as the funnelling effect, these places receive very high rainfall.

Seasons

Unlike the equatorial climate which does not have distinct seasons, monsoon climate experiences striking differences in weather conditions based on the seasons.

1. **The hot dry season**
    - This lasts from March to mid – June.
    - The sun is in a northward shift to the Tropic of Cancer. This causes the temperatures to rise sharply.
    - Mean temperatures during the day cross 35 degrees centigrade in Central India. It can reach as high as 44 degrees centigrade in Sindh and also in south India.
    - In coastal areas, the temperatures are not so high, due to the influence of sea breezes.
    - Except for the occasional thunderstorms, there is little rainfall during this season.
2. **The rainy season**
    - This lasts from mid – June to September
    - The rains begin with the 'burst' of monsoon over the subcontinent. It results in torrential rainfall throughout the country.
    - Over 70 percent of the rainfall which the country receives in a year occurs in this season.
    - This can be termed a typical characteristic feature of monsoon type of climate i.e., concentrated heavy rainfall during the summer months.
3. **The cold dry season**
    - This season begins in October and lasts until February.
    - Also known as the season of retreating monsoon. As the sun begins its southward shift, south-west monsoon begins to retreat southwards until it leaves the Indian landmass completely.
    - The temperatures over the landmass begin to fall creating a high-pressure region over Indian subcontinent compared to the surrounding seas. This causes the winds to blow away from the landmass towards the sea.
    - The winds begin to blow from the northeast direction over the Bay of Bengal and cause some rainfall along the south-east coastal landmass of India in the months of November and December.
    - In the north, the Western Disturbances bring some amount of rain and snow, otherwise, the region remains dry. Frontal (cyclonic) rainfall due to the western disturbances is essential for the survival of winter crops.

Monsoon Forests

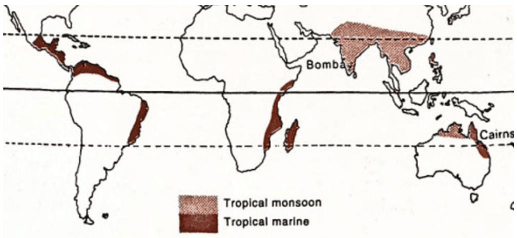
- Monsoon forests, also known as tropical monsoon forests, consist primarily of deciduous trees that shed their leaves during dry or drought seasons to minimize water loss through transpiration. These forests can be classified into two types: moist deciduous, where annual rainfall exceeds 150 cm, and dry deciduous, where annual rainfall is less than 150 cm.
- Monsoon forests are composed of broad-leaf hardwood trees, similar to those found in equatorial rainforests. However, these forests are less dense and exhibit less diversity in both plant and animal species. When rainfall

amounts surpass 200-250 cm, equatorial-type evergreen rainforests can be found, such as in the southern Western Ghats, northeast forests, and the Andaman and Nicobar Islands of India, as well as in the islands of Southeast Asia.

- In areas with scarce rainfall, savanna-type grasslands with scattered trees can be observed. As a result, monsoon vegetation displays a wide range of variation, from dense forests to sparse, thorny scrublands (savannas).

Economy

- These regions have a high population density.
- Subsistence agriculture is the main type of crop cultivation, although shifting cultivation and plantation agriculture is also practised.
- In the plains of north India, cereals like rice, wheat, maize etc. are cultivated apart from jute, sugarcane, and spices.
- In the highlands of south and east India, plantation crops can be found – tea, coffee, rubber, banana etc
- Lumbering is an important activity with the forest yielding durable hardwood. Teak is an important deciduous timber variety found in central India as well as in Myanmar. Other timber varieties include Sal, Acacia, Eucalyptus, Neem, Mango etc. Bamboo is also an important source of timber



Desert Climate

- Desert regions are characterized by very little rainfall and scanty vegetation. The length of the growing period is limited to a small rainy season.
- The landscape of the region is devoid of trees and animals due to the lack of moisture and food.
- They can be of two types

  (i) hot deserts – like Saharan desert

  (ii) mid-latitude deserts – like Gobi desert.

Hot deserts – distribution

- Important hot deserts of the world are situated on the western edges of the continents between latitudes 15 to 30 degrees north and south.
- Sahara desert is the largest of hot deserts, covering an area of 3.5 million square miles. Other prominent hot deserts include the Great Australian Desert, Arabian desert, Kalahari desert, Thar desert etc.
- Hot deserts are also found in the Americas. In North America, they are known by the names of Mohave, Sonoran, Californian, and Mexican deserts. They extend between USA and Mexico. In South America, the Atacama desert, or the Peruvian desert is located.

Hot deserts – Temperature

- Hot deserts are among the warmest places on Earth, with consistently high temperatures throughout the year. These areas do not experience a distinct cold season, and the average summer temperatures consistently exceed 30 degrees Celsius. The highest recorded temperature in a hot desert was in Libya in 1922, reaching a scorching 57 degrees Celsius.
- The extreme heat in hot deserts can be attributed to several factors, including cloudless skies, intense sunlight, dry air, and a high rate of evaporation. However, the coastal regions of these deserts tend to have a more moderate climate due to the influence of nearby seas and the cooling effect of cold ocean currents, which help to lower the average temperatures in these areas.
- In contrast, the interior regions of hot deserts experience more extreme temperature fluctuations, with sweltering summers and frigid winters. The difference in temperature between day and night, known as the diurnal temperature range, is particularly pronounced in these areas. The intense solar radiation during daytime, combined with dry air and a lack of cloud cover, causes temperatures to soar as the sun rises. Conversely, as the sun sets, temperatures quickly drop below the average due to the continuous loss of heat through radiation and the absence of clouds to retain warmth. As a result, the average diurnal temperature range in hot deserts is around 14 to 25 degrees Celsius.
- Additionally, during winter nights, it is common for frost to form in hot deserts, despite the generally high temperatures associated with these environments.

Hot deserts – Precipitation

- In hot deserts, the average annual precipitation is less than 25 cm, making these regions extremely dry. These deserts are found within the Sub-Tropical High-Pressure Belts, also called the Horse Latitudes, which have descending air masses that create unfavorable conditions for cloud formation and precipitation.
- The Trade Winds, which blow away from the shore, prevent moisture-laden winds from reaching these regions from the sea. Moreover, the Westerlies, which blow towards the shore, do not pass over desert areas, further reducing the likelihood of precipitation.
- The winds that do blow over deserts come from colder regions, which results in a lower relative humidity as they pass over the desert. This decreases the possibility of water vapor condensation and subsequent precipitation. In addition, the relative humidity decreases from 60 percent in coastal areas to less than 30 percent in the interiors, increasing evaporation rates and diminishing any chances of precipitation, thus making these deserts areas of constant drought.
- Cold currents that flow along the west coasts of continents also contribute to the dry nature of these deserts. Moisture-laden winds from the sea often condense into mist or fog when they encounter these cold currents, leaving only dry winds to blow over the deserts.
- However, some convectional rainfall can occur in these regions as brief, intense thunderstorms. These sudden downpours can sometimes lead to disastrous landslides. The Atacama Desert is the world's driest region, with an annual precipitation of less than 2 cm.

Mid-Latitude deserts – distribution

- These desert are often situated on plateaux and are a part of continental interiors.
- They include Gobi desert, Turkestan desert, Patagonian desert etc.
- In India, Ladakh desert falls under this category.

Mid-latitude deserts – climate

- Mid-latitude deserts share several climatic similarities with hot deserts. These deserts are typically located far from the coast or surrounded by tall mountains, which prevents them from receiving moisture-rich winds from nearby seas. As a result, the average annual precipitation in these areas does not exceed 25 cm.
- Occasionally, depressions may reach these deserts in Asia, leading to light rainfall during winter months. Additionally, convectional rainfall can occur during summer months.
- One key difference between mid-latitude and hot deserts is that the former experiences a much wider range of annual temperatures, largely due to the phenomenon of continentality. Continentality refers to the climatic influence of being located on a large landmass, particularly at a significant distance from the coast.
- In mid-latitude deserts, winters can be characterized by freezing temperatures and strong, cold winds. During the summer months, ice may thaw, sometimes causing floods in certain areas. Overall, the extreme temperature fluctuations in these deserts can be attributed to their inland location and the influence of continentality.

Desert Vegetation

- Desert environments contain various forms of plant life, such as grasses, shrubs, and weeds. These plants may not always appear green, as they often remain dormant until they receive water from infrequent rainfall. The most prevalent type of plant life in both hot and mid-latitude deserts is xerophytic, or drought-resistant, scrub.
- Some key species of xerophytic vegetation include bulbous cacti, long-rooted wiry grasses, thorny bushes, and dwarf acacia. In certain areas with an abundance of groundwater, one can find clusters of date palms, particularly in hot deserts. The plant life that thrives in these arid regions is specially adapted to handle extreme dryness.
- Soil in these areas is typically low in humus content due to the lack of moisture which slows down the decomposition of organic matter. Desert shrub vegetation often has an extensive system of long roots that grow in search of groundwater. These plants possess few, if any leaves, and their foliage is often hairy, waxy, or needle-shaped to minimize water loss through transpiration.
- The seeds of desert plants have unique protective mechanisms while they remain dormant, such as thick, tough outer surfaces. When these seeds come into contact with water from rain, they quickly germinate.

Which of the following is a characteristic of the savanna climate?

A. High rainfall throughout the entire year.

B. A distinct dry season occurring during the winter months.

C. Cold temperatures during the winter season.

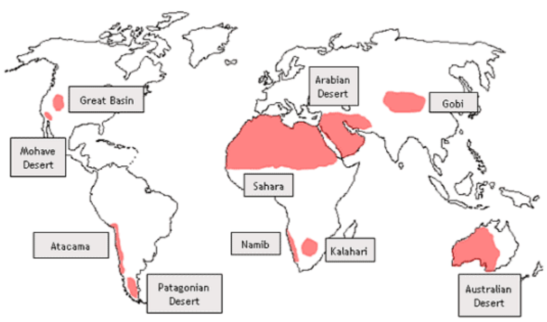
D. Dense forests with a high diversity of plant and animal species.

Life in the deserts

Although deserts are known for their harsh conditions, various types of human settlements have managed to adapt and thrive in these environments:

- **Primitive hunters and gatherers:** These are indigenous tribes that do not engage in agriculture or animal domestication. Examples of such tribes include the Bushmen of the Kalahari Desert and the Bindibu, or Aboriginal people of Australia.
- **Nomadic herdsmen:** These groups rely on a livestock-based economy, traversing the deserts with their herds in search of water and grazing areas. Notable examples include the Bedouins of Arabia, the Tuaregs of the Sahara, and the Mongols of the Gobi Desert.
- **Settled cultivators:** These communities have established themselves near rivers, such as the Nile in Egypt, Indus in Pakistan, Colorado in the USA, and Tigris-Euphrates in Iraq. They grow crops like wheat, barley, sugarcane, fruits, and vegetables to sustain themselves.
- **Mining settlers:** These settlements are often centered around the extraction of valuable resources, such as gold mines in Australia, diamond mines in the Kalahari, copper mines in Chile, silver mines in Mexico, and oil in the Persian Gulf countries.

Despite the challenges posed by the desert environment, these diverse groups of people have found ways to adapt and survive in their respective regions.



Steppe Climate

- The term steppe refers to a region which is a semi-desert with a grassland or shrub vegetation.
- Steppes are intermediate regions, not receiving enough rainfall to support a forest but are also not as dry as a desert.
- Steppe Climatic region is also known as Temperate Grasslands.
- These grasslands are some of the most developed agricultural fields and are termed as grain baskets.
- Livestock ranching is another major activity carried out in these areas due to the availability of natural grasses.

Distribution

- Steppes are found in the continental interiors.
- They are usually found in the temperate latitudes and hence come under the influence of Westerly winds.
- Steppes are characterized by vast grasslands which are, by and large, devoid of trees.
- Steppes typically refer to the vast temperate grasslands of Eurasia, which stretch between the Black Sea coast on the east to the Altai mountains in the west, covering a length of over 2000 miles.
- Steppes are known by their regional names in different parts of the world. They include,
- Prairies – North America
- Pustaz – Hungary
- Pampas – Argentina and Uruguay
- Velds (High Veld) – South Africa
- Downs – Australia
- Canterbury – New Zealand

Precipitation

- The average annual rainfall over the steppes varies from 25 to 75 cm, depending upon the region.
- The highest rainfall occurs in the spring season, or just prior to the onset of summers. In the northern hemisphere, it occurs in the months of June and July.
- During the winters, Westerlies bring in occasional depressions which often cause snowfall over these regions. However, the overall precipitation in the winters is low, at an average of 25 cm.
- In the southern hemisphere, due to a larger influence of maritime weather, higher rainfall occurs over these regions as compared to their counterparts in the northern hemisphere.

Temperature

- These regions are under the effect of continentality and hence experience extremities in temperature.

- Summers are warm with the average temperature in the range of 18-20 degrees centigrade.
- Winters are usually cold with occasional snowfall.
- The steppes in the northern hemisphere have a very high annual range of temperatures.
- To its contrast, the steppes in the southern hemisphere, due to maritime influence, have a moderate climate throughout the year.

Winds

- The dominant winds in these regions are the Westerlies, which bring precipitation during the winter months. In addition to these, numerous local winds significantly influence the area's weather conditions. These winds have various names, such as the cold, dry Mistral in France; the warm, dry Loo in the Gangetic plains; the Sirocco in the Sahara; and the Foehn in the Alps.
- The Chinook is a local, hot, and dry wind that blows across the North American Prairies. As a katabatic wind, it descends from the Rocky Mountains and flows in a southwesterly direction. This wind causes a rapid increase in temperature, often raising it by more than 5 degrees Celsius within just 20 minutes.
- The Chinook wind is beneficial to local agriculture as it helps melt snow on the pastures, making it easier for animals to graze. Overall, these various local winds play a crucial role in shaping the weather patterns and climate of their respective regions.

Vegetation

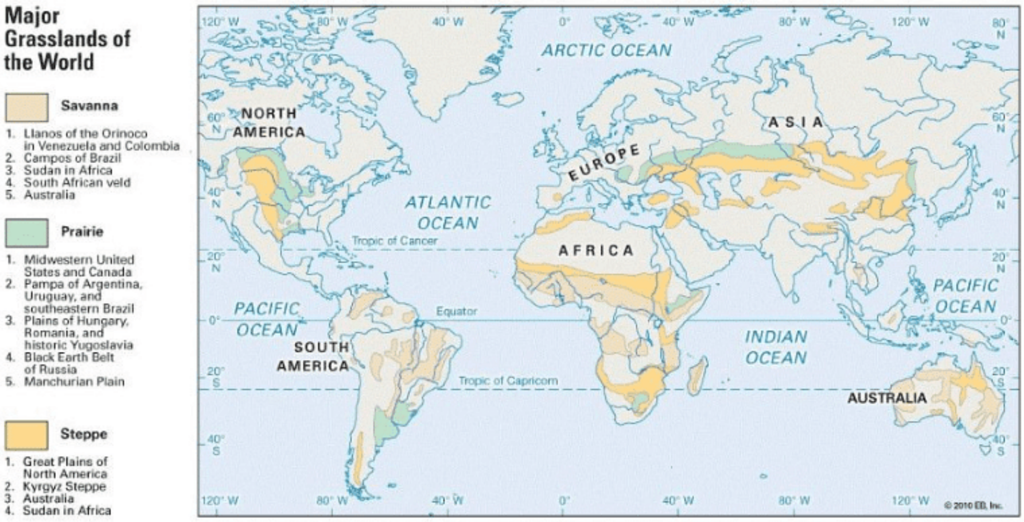
- In contrast with the tropical grasslands of savanna, which are interspersed with trees, temperate grasslands are practically treeless. Also, the grass in these grasslands is much shorter as compared to that in savanna
- However, the grass is fresh and nutritious, unlike the coarse grass found in the savannas. This is mostly true for the prairies of North America, and also the Chernozem grasses of Ukraine. The prairie soils are also nutritious black earth soils.
- The grass is lean, thin and scattered.
- This makes them ideal for large-scale livestock rearing, also known as ranching.
- The grass growing season is throughout the year, uninterrupted by seasonal variations in temperature and precipitation
- Towards the poleward extension of prairies, there is a transitional zone of forests in which conifers can be found.
- Within the farmlands of steppes, trees are planted around the croplands to shield them from strong winds.

Economy

- Grasslands, such as savannas, steppes, prairies, and pampas, have diverse economic activities depending on their location and resources. While savannas are home to some of the largest terrestrial animals, steppes have less animal diversity. In the Eurasian steppes, horses are commonly found roaming the open landscape.
- Agriculture is a significant economic activity in grasslands, particularly in prairies, due to the development of irrigation canals in the last century. Large-scale mechanized cultivation is practiced in these areas, making them some of the most productive agricultural regions globally. Prairies are often referred to as the world's granaries due to their extensive wheat and maize production.
- Other grasslands, such as the Pampas of Argentina and the Downs of Australia, are also known for their wheat cultivation. The mostly level terrain of the steppes makes plowing and harvesting more manageable, especially with the aid of machinery.
- Livestock ranching is another vital economic activity in grasslands. The less nutritious tufted grass has been replaced with more nutritious Lucerne or alfalfa grass, facilitating large-scale cattle and sheep rearing. As a result, these regions have become global leaders in animal ranching. Grasslands are also the largest producers of dairy and other animal products, such as milk, butter, cheese, beef, and animal skins. These products are exported worldwide, aided by easy access to containerized cargo and refrigerated ships.
- In the vast Eurasian steppes, nomadic herding is practiced by native tribes such as the Kazakhs and Kirghiz. Long periods of drought due to unreliable rains in the continental interiors have made crop cultivation and settled animal rearing almost impossible in these areas. However, in some regions where water is available, large-scale collective farming has been introduced by Russia.

Different grassland regions are known for specific economic activities, including:

- **Prairies:** Wheat cultivation and livestock ranching.
- **Velds:** Sheep and cattle rearing, maize cultivation.
- **Pustaz:** Wheat and beet sugar cultivation.
- **Pampas:** Wheat cultivation, dairy and beef product exports.
- **Downs and Canterbury:** Wool production from Merino sheep, dairy products.



Conclusion

Climate refers to the long-term atmospheric conditions in a specific location, encompassing various elements such as temperature, humidity, precipitation, atmospheric pressure, and wind patterns. The world's diverse climates give rise to unique ecosystems and human settlements, each adapted to their specific environments. From hot, wet equatorial forests to the arid desert landscapes and temperate grasslands, these climatic regions are home to distinct vegetation, wildlife, and economic activities. Understanding the complex interactions between various meteorological variables and their effects on the world's climates is crucial for predicting and mitigating the potential impacts of climate change.

What is the difference between weather and climate?

Weather refers to the short-term state of the atmosphere in a specific location, including factors such as temperature, humidity, precipitation, air pressure, wind, and cloud cover. Climate, on the other hand, refers to the long-term synthesis of weather conditions that have occurred in a particular area over an extended period, typically 30 years, providing an overview of the average weather patterns in a specific region.

What are the primary factors that contribute to a region's climate?

The primary factors that contribute to climate include sunlight exposure, temperature fluctuations, levels of humidity, different forms of precipitation (such as rain or snow) and their frequency, atmospheric pressure, and wind patterns in terms of speed and direction.

How are climatic regions classified, and what are some examples of different climatic regions?

Climatic regions are classified based on the combination of meteorological variables such as temperature, precipitation, and wind patterns. Some examples of different climatic regions include hot, wet equatorial climate; savanna or Sudan climate (tropical wet and dry climate); tropical monsoon climate; desert climate; and steppe climate.

How do the vegetation and wildlife differ between savanna and steppe climates?

Savanna climates are characterized by tall grasses and short trees, often referred to as 'bush-veld' or 'parkland'. The wildlife in savanna ecosystems includes large herbivores such as zebras, giraffes, elephants, and antelopes, as well as carnivores such as lions, hyenas, leopards, and panthers. In contrast, steppe climates are characterized by shorter grasses and are practically treeless. The wildlife in steppe ecosystems is less diverse than in savannas, but these areas are ideal for large-scale livestock rearing or ranching.

How do human settlements adapt and survive in desert climates?

Human settlements in desert climates adapt and survive through various means, such as engaging in subsistence agriculture, nomadic pastoralism, settled cultivation near rivers, or mining

settlements focused on the extraction of valuable resources. Despite the challenges posed by the desert environment, these diverse groups of people have found ways to adapt and thrive in their respective regions.

1. What is a hot, wet equatorial climate?

Ans. A hot, wet equatorial climate is a climate type characterized by high temperatures and abundant rainfall throughout the year. It is typically found in regions near the equator, such as the Amazon rainforest and parts of Southeast Asia.

2. What are the main features of a hot, wet equatorial climate?

Ans. The main features of a hot, wet equatorial climate include high temperatures averaging around 27-30°C (80-86°F), high humidity, and heavy rainfall throughout the year. The rainfall is often in the form of intense thunderstorms, which contribute to the lush vegetation and dense forests in these regions.

3. What are the factors that influence a hot, wet equatorial climate?

Ans. The factors that influence a hot, wet equatorial climate include the proximity to the equator, the presence of warm ocean currents, and the prevailing wind patterns. The position near the equator ensures high solar radiation, leading to high temperatures. Warm ocean currents contribute to the moisture in the air, and the prevailing winds help bring in moisture-laden air masses from the ocean.

4. What are the effects of a hot, wet equatorial climate on vegetation and biodiversity?

Ans. The hot, wet equatorial climate supports a diverse range of vegetation and high biodiversity. The abundant rainfall and high temperatures create ideal conditions for the growth of dense forests and lush vegetation. This climate zone is home to numerous species of plants and animals, including unique and endemic species found nowhere else in the world.

5. How does a hot, wet equatorial climate impact human activities and settlements?

Ans. The hot, wet equatorial climate poses challenges for human activities and settlements. The high humidity and heat can be uncomfortable for humans, and the constant rainfall can lead to difficulties in agriculture and infrastructure development. However, these regions also provide important resources such as timber, minerals, and freshwater, which can support human settlements and economic activities if managed sustainably.

Applied Climatology & Urban Climate

Applied Climatology

- **Climatology's Role in Various Sectors:** The growing impact of weather and climate on our day-to-day lives and long-term activities has led to increased attention from climatologists. Since the second world war, there has been a growing awareness of the potential applications of climatology in various areas, such as water resource development and disease eradication.
- **Climate and Natural Vegetation:** Natural vegetation is an indicator of climate, and their interdependence is vital for understanding their influence on one another. Knowing the optimal climatic conditions for various stages of forest growth is essential for those involved in afforestation, timber production, and watershed management. In silvicultural practices, the interrelationship between forests and climate is considered for maximizing yields.
- **Climate and Agriculture:** Food is a fundamental human need, and climate and vegetation are closely interconnected. Weather components, such as temperature, precipitation, humidity, and wind, play a significant role in crop production. For example, frost-sensitive crops like coffee, bananas, and sugarcane require specific temperature ranges for optimal growth. In hilly regions, citrus and other sensitive crops are planted on sun-exposed slopes to avoid frost-prone valley areas.
- **Climate and Animal Husbandry:** Meat and milk products come from animals that rely on pastures and feed crops, which are heavily influenced by climatic factors. Amongst these factors, temperature plays a crucial role in animal productivity. High temperatures can reduce milk production and the overall yield of flesh and fat from animals. Precipitation also affects the availability of grass in pastures, and extreme humidity levels can cause discomfort to animals. To counter these climatic impacts, animal shelters with controlled temperature and protection from adverse weather conditions are used in animal husbandry.
- **Climate and Housing:** Climatic conditions significantly influence housing types. For example, igloos are built in polar regions as homes for Eskimos, while open houses are found in tropical areas. In building and architectural climatology, micro-climatic conditions are influenced by factors such as local relief, nearby structures, landscaping, water bodies, and industrial waste. Green buildings are designed to maximize the use of natural resources, such as sunlight and wind, and incorporate climate considerations into their design. In tropical countries, double roofs are used to facilitate air movement and minimize heat transfer into the building. Similarly, roof designs in different climatic conditions consider factors such as precipitation and snowfall.

Air Pollution and Health

- Medical climatology is the study of the relationship between human health and climate or weather. Local winds, such as the loo or cold waves, can cause irritability, depression, dizziness, and hypertension. In some areas like Bangalore, a high concentration of pollens in the air can lead to breathing problems. As a result, the local government in Bangalore has restricted the planting of flowering saplings in parks during certain times of the year to reduce pollen levels in the air.
- Cities emit a significant amount of pollutants into the atmosphere, which can transform into acids through chemical reactions and fall as acid rain. Monitoring the atmospheric concentrations of these chemicals can help regulate industries and protect sensitive areas, such as the area surrounding the Taj Mahal in Agra, where vehicular traffic and industry have been banned. Acid rain can also be harmful to plant and marine life.
- Certain diseases are associated with specific climates or seasons. For example, cold seasons can control insect populations by forcing them into hibernation, which is why tropical diseases like dengue and malaria are more prevalent in tropical and subtropical regions. Other diseases, such as pneumonia, influenza, and measles, are closely associated with specific seasons or climates. This association allows governments to issue warnings and take measures to reduce the impact of these diseases. In South Asia, municipal bodies ensure that water does not accumulate in urban areas during

monsoon seasons to prevent the spread of malaria and other vector-borne diseases.

What are the main factors contributing to the urban heat island effect?

A. Heat from fires, industry, and homes; heat-conserving properties of building materials; blanketing effect of atmospheric pollution
B. Increased use of air conditioning in cities; increased levels of noise pollution; increased use of public transportation
C. Rising sea levels; increased frequency of storms; altered precipitation patterns
D. Decreased humidity in cities; increased tree density; increased use of green roofs

Climate and Economy

Climate research plays a crucial role in benefiting various industries, including insurance, tourism, construction, energy, transport, sports, retail food, and retail clothing. By understanding and analyzing climate patterns and extreme weather events, these industries can adapt and make informed decisions to minimize risks and costs.

- Insurance companies, for example, are able to offer financial protection against climate-related damages, such as floods, frost, and wind. Climate research helps insurers quantify the probability of extreme events, provide year-ahead forecasts, and identify vulnerable regions. This information can reduce costs and improve risk management strategies.
- Tourism is directly influenced by climate, as there is often a peak season for tourists in specific destinations based on the local climate. For instance, cold mountainous regions tend to attract more visitors during the summer months. Understanding climate patterns helps the tourism industry better plan and cater to the needs of tourists.
- The energy sector also benefits from climate research, particularly in the development of renewable energy sources like wind and hydroelectric power. Wind atlases and data on water supply from glaciers and rainfall help determine the optimal location and height for wind turbines and hydroelectric plants.
- Transportation industries such as aviation and shipping are directly impacted by weather and climate conditions. Extreme weather events, like fog and cold waves, can disrupt flight schedules, while high-altitude ports may become inaccessible due to freezing during winter. Climate research helps transportation industries better prepare for and adapt to these challenges.
- In addition to these industries, humans and other mammals have evolved internal temperature regulation systems that help maintain stable core body temperatures in different climates. Cultural habits and technologies have also been developed to help people adapt to various climate conditions. For example, people in colder climates may consume more alcohol to increase blood flow and provide a sensation of warmth.
- Technological advancements have enabled researchers to survive in extreme climates, such as the cold Antarctic and Arctic regions or hot tropical areas. Air conditioning, for example, allows people to live comfortably in hot climates. Overall, climate research plays a vital role in helping various industries and individuals adapt and thrive in different climates and weather conditions.

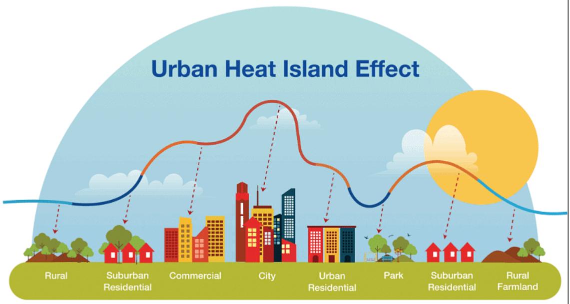
Urban Climate

Urban regions around the world exhibit a unique climate that differs from the typical regional patterns. This is because the process of urbanization modifies the physical environment, leading to changes in energy, moisture, and air movement near the surface. The concentration of buildings in urban areas can impact wind and atmospheric conditions as much as a large forest.

- An urban area alters various aspects of the atmosphere, such as air composition, temperature, and precipitation patterns. Wind speeds tend to be lower in cities compared to open areas due to the obstructive nature of urban structures. The actual impact depends on factors such as street design, season, and time of day. Winds usually flow down streets parallel to their general direction, especially in cities with high-rise buildings and canyon-like streets. In contrast, streets at right angles to the wind may experience strong lee effects. During the day, wind speeds in cities are significantly lower than in surrounding areas, but at night, turbulence over the city reduces the contrast. Rural-urban differences are more pronounced during strong winds, making the effects more noticeable in winter than in summer.

- Urban areas typically absorb less water per area than rural regions, as much of the city is covered with pavement or buildings. In some cases, this necessitates specific measures to reduce the risk of localized flooding during heavy rainfall. Construction activities in flood-prone areas can increase the duration and intensity of flooding. Cities generally have lower humidity than rural or forested areas due to factors such as rapid surface runoff, lower vegetation density, and the absence of water bodies. However, under certain conditions, the thermal and turbulence effects over cities may trigger precipitation or thunderstorms. Many cities experience more light rain and thunder than surrounding areas, resulting in a slight increase in total precipitation.

Urban Heat Island: An "urban heat island" (UHI) refers to built-up areas that are warmer than nearby rural areas due to human activities. This phenomenon was first studied and documented by Luke Howard in the 1810s. The temperature difference is usually greater at night than during the day and is most noticeable when winds are weak. The average temperature difference can be several degrees between the city center and surrounding fields, sometimes reaching as high as 10°C.



Urban Heat Islan

There are three main factors behind the urban heat island effect:

1. Direct production of heat in cities from fires, industry, and homes.
2. Heat-conserving properties of the bricks and materials used in building cities.
3. The blanketing effect of atmospheric pollution on outgoing radiation.

Heat trapped in concrete buildings and pavements during the day is released slowly in the form of long-wave radiation, making the cooling process slow. Additionally, cities have less vegetation, which means they lose the shade and cooling effect of trees, the low albedo of their leaves, and the removal of carbon dioxide. Tall buildings in urban areas also provide multiple surfaces for reflecting and absorbing sunlight, increasing the heating efficiency. Furthermore, these buildings inhibit cooling by convection and prevent pollution from dissipating. Chemicals emitted by cars and industries often trap sunshine, creating more heat. All these factors change the energy balance of an urban area.

As a city grows, its area and average temperature tend to increase. For example, Los Angeles has experienced an average temperature rise of approximately 0.5°C every decade since World War II. Other cities have seen increases of 0.1°-0.4°C each decade. The urban heat island effect varies for each city based on its structure, as parks and greenbelts reduce temperatures while central business districts, commercial areas, and suburban housing tracts are warmer.

Urban heat islands impact city residents by increasing discomfort, raising energy consumption for cooling purposes, and decreasing air and water quality. They also enhance photochemical reactions, which contributes to the formation of smog and clouds.

To counteract the urban heat island effect, several strategies can be employed:

- Use light-colored or reflective materials in construction to increase albedo. Dark surfaces can be up to 21°C hotter than light surfaces, which contributes to increased cooling needs. By switching to light-colored roofs, buildings can use 40% less energy.
- Implement green roofs, where a building's roof is partially or completely covered with vegetation and a growing medium over a waterproofing membrane. Rooftop ponds can also be used to treat grey-water. Green roofs serve multiple purposes, such as absorbing rainwater, providing insulation, creating wildlife habitats, and helping to lower urban air temperatures. They also offer financial benefits, such as reduced energy usage, tax incentives, and an increased lifespan for the roof.

Green Roof

- Green Building is a construction approach that emphasizes resource efficiency and environmental

sustainability. This method involves optimizing the use of sunlight within the building, which helps to reduce its overall energy consumption and thus, minimizes the impact of Urban Heat Island (UHI) effect.

- Another strategy to mitigate the UHI effect is to increase the presence of well-maintained vegetation, particularly trees. Studies have shown that the cooling potential per area is significantly higher in streets with a higher density of trees. This is because trees increase evapotranspiration, which in turn lowers the air temperature. As a result, trees can contribute to reducing energy costs by 10-20%.
- Heat island mitigation is usually incorporated into a community's efforts towards energy conservation, air quality improvement, water management, or overall sustainability. Mitigation activities can vary from voluntary initiatives, such as demonstrating the use of cool pavements, to policy-driven actions like enforcing cool roof requirements through building codes. Most of these mitigation measures offer multiple benefits, including cleaner air, enhanced human health and comfort, reduced energy expenses, and decreased greenhouse gas emissions.

Atmospheric Pollution Over Cities

- Air pollution refers to any substance introduced into the atmosphere by humans that negatively impacts living organisms and the environment. In urban areas, air pollution typically consists of soot, ash, gases, fumes, smoke, and oxides of sulfur, carbon, and nitrogen. Carbon dioxide and other greenhouse gases, such as methane, are the primary pollutants responsible for global warming.
- Sulfur dioxide and related chemicals are primarily known for causing acid rain. These pollutants can increase a city's albedo, or the amount of sunlight reflected back into space, by forming a blanket of radiation over the city. Additionally, they can act as condensation nuclei, which are particles on which water vapor condenses to form clouds.
- Under normal circumstances, much of this pollution would be dispersed upwards by turbulence and removed by stronger winds at higher altitudes. However, tall buildings in cities can obstruct the free movement of these particles, leading to higher concentrations of pollution. The highest levels of pollution occur when there are low wind speeds, temperature inversions, and high relative humidity.
- Addressing air pollution in cities requires a multifaceted approach, involving both civil society and individual residents. On a larger scale, governments can implement legislation, tax incentives, and other initiatives to reduce air pollution. Civil society can contribute by raising environmental awareness among citizens and promoting activities such as urban forestry.

In summary, atmospheric pollution in cities is a complex issue caused by various human activities, resulting in the release of harmful substances into the atmosphere. These pollutants can have severe consequences for both the environment and human health. Addressing this issue requires collaborative efforts from governments, civil society, and individuals to implement effective strategies to reduce air pollution in urban areas.

Urban Climate and Global Climate Change

- Urban climate changes are closely connected to global climate change. Cities, as hubs for socioeconomic activities, generate significant amounts of greenhouse gases, primarily CO2, due to human activities such as transportation, construction (e.g., concrete production), and energy consumption for heating and cooling purposes. Cities are the primary consumers of energy, which is primarily produced using fossil fuels.
- Many urban areas are susceptible to the anticipated impacts of climate change, such as rising sea levels, temperature fluctuations, alterations in precipitation patterns, and increased storm frequency. This vulnerability is due to factors such as their location along or near coastlines, the presence of distinct urban heat islands, and the production of atmospheric pollution.

Which of the following strategies can help counteract the urban heat island effect? A. Increasing the use of dark-colored materials in construction **B.** Implementing green roofs and rooftop ponds **C.** Decreasing the presence of vegetation in cities **D.** Encouraging the use of non-reflective surfaces on buildings

Conclusion

The study of applied climatology and urban climate is crucial for understanding the impacts of climate change on various sectors, such as agriculture, animal husbandry, housing, health, and economy. The urban heat island effect and atmospheric

pollution in cities further contribute to global climate change, exacerbating its negative consequences. Addressing these issues requires concerted efforts from governments, civil society, and individuals to implement effective strategies and adopt sustainable practices to mitigate climate change and improve the quality of life in urban areas.

What is the role of climatology in various sectors, such as agriculture and housing?

Climatology plays a crucial role in various sectors by helping them understand and adapt to different climate and weather conditions. For example, in agriculture, weather components like temperature, precipitation, and humidity can impact crop production, while in housing, climatic conditions can influence building design and materials used to maximize energy efficiency and comfort.

How does urban climate differ from the regional climate, and what factors contribute to the urban heat island effect?

Urban climate differs from regional climate due to the unique features of urban areas, such as the concentration of buildings, paved surfaces, and human activities. The urban heat island effect occurs when built-up areas are warmer than nearby rural areas due to factors like heat production from human activities, heat-conserving properties of building materials, and the blanketing effect of atmospheric pollution on outgoing radiation.

What are some strategies to mitigate the urban heat island effect and reduce air pollution in cities?

Some strategies to mitigate the urban heat island effect include using light-colored or reflective materials in construction to increase albedo, implementing green roofs or rooftop gardens, and increasing the presence of well-maintained vegetation, particularly trees. To reduce air pollution in cities, governments can implement legislation and incentives to reduce emissions, while civil society can raise environmental awareness and promote activities such as urban forestry.

How are urban climate changes connected to global climate change, and how are cities vulnerable to the impacts of climate change?

Urban climate changes are connected to global climate change because cities generate significant amounts of greenhouse gases due to human activities like transportation, construction, and energy consumption. Cities are vulnerable to the impacts of climate change due to factors such as their location along coastlines, the presence of urban heat islands, and the production of atmospheric pollution.

What measures can governments and individuals take to address atmospheric pollution in urban areas?

Governments can implement legislation, tax incentives, and other initiatives to reduce air pollution in urban areas. They can also invest in renewable energy sources and promote public transportation. Individuals can contribute by using energy-efficient appliances, reducing their use of private vehicles, and participating in urban forestry or other environmental initiatives.

5. What are some frequently asked questions about applied climatology and urban climate?

Ans. Some frequently asked questions about applied climatology and urban climate may include: - How does climate change affect urban areas? - What are the strategies to reduce the urban heat island effect? - How can urban planning promote climate resilience? - What are the impacts of urbanization on local weather patterns? - How can cities adapt to climate change and mitigate its impacts? These questions reflect common areas of interest and concern regarding the relationship between climate, urbanization, and planning for sustainable and resilient cities.

1. What is applied climatology?

Ans. Applied climatology is a branch of climatology that focuses on the practical application of climate knowledge to various fields such as agriculture, urban planning, water resource management, and disaster preparedness. It involves analyzing historical climate data, understanding climate patterns and trends, and using this information to make informed decisions and develop strategies to mitigate the impacts of climate variability and change.

2. How does climate affect the economy?

Ans. Climate can have significant impacts on the economy through various channels. Extreme weather events such as hurricanes, droughts, and floods can damage infrastructure, destroy crops, and disrupt supply chains, leading to economic losses. Changes in temperature and precipitation patterns can also affect agriculture, affecting crop yields and livestock productivity. Additionally, changes in climate can impact sectors such as tourism, energy, and insurance, further influencing the overall economic performance of a region or country.

3. What is urban climate?

Ans. Urban climate refers to the climate conditions and characteristics within urban areas, which can differ from the surrounding rural areas due to the presence of buildings, roads, and other urban infrastructure. Urbanization can lead to the formation of urban heat islands, where cities experience higher temperatures compared to their rural surroundings. Urban climate also influences factors such as air quality, wind patterns, and precipitation, which can have implications for human health, energy consumption, and urban planning.

4. How can applied climatology be useful in urban planning?

Ans. Applied climatology can be highly valuable in urban planning as it provides insights into the local climate conditions and their interactions with urban environments. By understanding the urban climate, planners can design cities and infrastructure that are more resilient to climate change, mitigate the urban heat island effect, optimize energy consumption, improve air quality, and enhance the overall livability of urban areas. Additionally, applied climatology can help identify vulnerable areas and inform strategies for climate adaptation and disaster risk reduction.

Air Masses and Fronts

Air Mass

- An air mass is a large body of air that has acquired specific characteristics in terms of temperature and humidity due to remaining over a homogeneous area for an extended period of time.
- These homogeneous areas can include vast ocean surfaces or expansive plains and plateaus. As a result,

the air mass exhibits minimal horizontal variations in temperature and moisture.

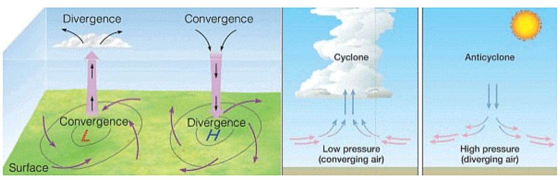
- Air masses play a crucial role in the global planetary wind system and are typically associated with specific wind belts. They can span from the Earth's surface to the lower stratosphere, stretching across thousands of kilometers.

Source regions

- Source regions refer to the homogeneous surfaces where air masses form. These regions play a crucial role in establishing heat and moisture equilibrium with the air masses above them. The primary source regions are located in the subtropical high-pressure belts, which give rise to tropical air masses, and around the poles, which serve as the source for polar air masses.
- As an air mass moves away from its source region, the upper level can maintain its physical characteristics for an extended period. This occurs because air masses are typically stable with stagnant air, which does not promote convection, or the vertical movement of air. In such stagnant air, processes like conduction and radiation are not very effective.

Conditions for the formation of Air masses

- For air masses to form, certain conditions must be met. Firstly, the source region, or the area where the air mass originates, should be large and have gentle, divergent air circulation (meaning the air is slightly at high pressure). Ideal source regions are areas with high pressure but minimal pressure difference or gradient.
- It is important to note that there are no major source regions for air masses in mid-latitudes, as these areas are predominantly affected by cyclonic and other weather disturbances.



Conditions for the origin of Air masses

- Homogeneous Surface
- Isotropic surface
- Lack of turbulence in the air
- Lack of convection in air
- Subsiding air with high pressure
- Atmospheric stability
- Kinetic energy of wind and friction

Size and dimension

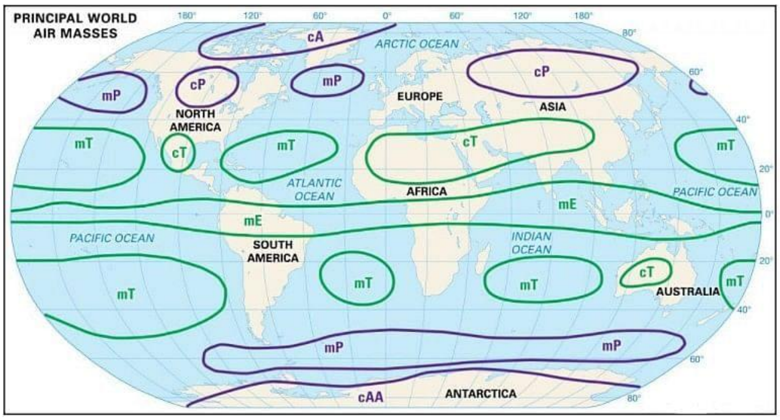
- Extend till Tropopause
- Width is hundreds of km
- Height varies b/w 8-12 km
- Latitudinal extent varies from 3000-6000 km

Classification of Air Masses

Air masses can be classified based on various factors, which include the nature of the surface, source region, temperature, and atmospheric conditions.

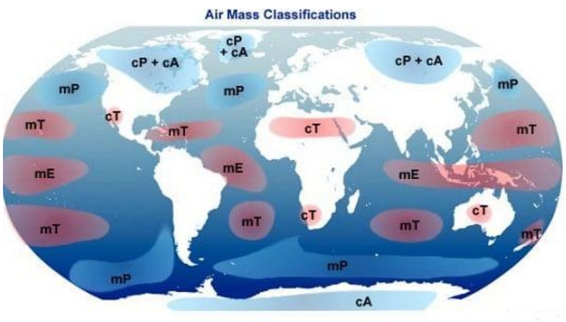
1. **Nature of Surface:** Air masses can be categorized as either continental or marine. Continental air masses form over land and are usually dry, whereas marine air masses form over water and are more humid.
2. **Source Region:** The source region refers to the area where the air mass originates. Polar air masses form in high latitude regions and are typically cold and dry, while tropical air masses form in low latitude regions and are warm and moist.
3. **Temperature:** Air masses can be classified as either cold or warm, depending on their temperature. Cold air masses have lower temperatures and warm air masses have higher temperatures. The interaction between cold and warm air masses often leads to changes in weather conditions.
4. **Atmospheric Conditions:** Based on the stability of the atmosphere, air masses can be classified as stable or unstable. Stable air masses are characterized by minimal vertical movement and uniform temperature and humidity, leading to stable weather conditions. Unstable air masses, on the other hand, have significant vertical movement, causing variations in temperature and humidity, and often leading to the development of storms and other severe weather events.

- **Broadly, the air masses are classified into polar and tropical air masses.**
- Both the **polar and the continental air masses can be either of maritime or continental types.**

- 

Air masses based on Source Regions

1. There are five major source regions. These are:
    - Warm tropical and subtropical oceans;
    - The subtropical hot deserts;
    - The relatively cold high latitude oceans;
    - The very cold snow-covered continents in high latitudes;
    - Permanently ice-covered continents in the Arctic and Antarctica.
2. Accordingly, the following types of airmasses are recognized:
    - Maritime tropical (mT);
    - Continental tropical (cT);
    - Maritime polar (mP);
    - Continental polar (cP);
    - Continental arctic (cA).
3. Tropical air masses are warm and polar air masses are cold.
4. The heat transfer processes that warms or cools the air take place slowly.



Cold Air Mass

- A cold air mass is one that is colder than the underlying surface and is associated with instability and atmospheric turbulence. (because of moisture and very low temperature)

Cold source regions (polar air masses)

- Arctic Ocean – cold and moist
- Siberia – cold and dry
- Northern Canada – cold and dry
- Southern Ocean – cold and moist

Warm Air Mass

- A warm air mass is one that is warmer than the underlying surface and is associated with stable weather conditions.

Warm source regions (tropical air masses)

- Sahara Desert – warm and dry
- Tropical Oceans – warm and moist

Influence of Air Masses on World Weather

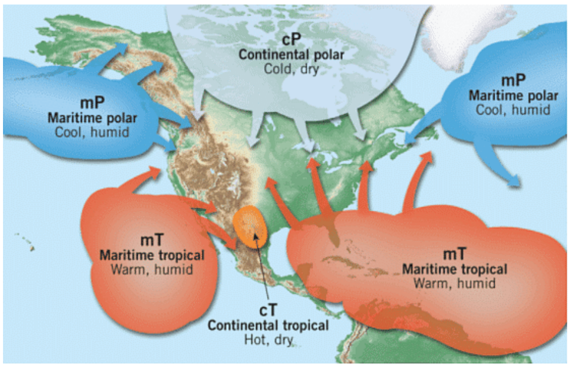
- Air masses play a significant role in shaping the world's weather, as they influence factors such as temperature distribution, moisture content, and atmospheric stability. These properties affect the weather conditions that accompany the air mass.
- Air masses transport moisture from oceans to continents, resulting in precipitation over land areas. This process helps maintain a balance of heat across various latitudes by transferring latent heat.
- Many weather phenomena, such as cyclones and storms, originate at the contact zones between different air masses. The characteristics of these air masses determine the specific weather conditions associated with these disturbances. In summary, the influence of air masses on global weather is vast, as they contribute to various weather events and help regulate temperature and moisture levels across the planet.

Continental Polar Air Masses (CP)

- Air masses known as Continental Polar (CP) originate from regions such as the Arctic basin, northern parts of North America and Eurasia, and Antarctica. These air masses are typically marked by their dry, cold, and stable nature.
- In the winter months, the weather associated with Continental Polar air masses is extremely cold, clear, and stable. However, during the summer, the weather conditions are less stable due to factors such as reduced anticyclonic winds, increased warmth from landmasses, and decreased snow cover.

Maritime Polar Air Masses (MP)

- These air masses originate from the oceanic regions located between 40° and 60° latitudes. They are initially continental polar air masses that have traveled over warmer ocean waters, causing them to heat up and gather moisture.
- The conditions in the source regions of these air masses are cool, moist, and unstable, making it difficult for them to remain stationary for extended periods. The weather associated with maritime polar air masses during winter includes high humidity, overcast skies, and occasional occurrences of fog and precipitation.
- In contrast, the summer weather associated with these air masses is generally clear, pleasant, and stable.



Continental Tropical Air Masses (CT)

- The source-regions of the air masses include tropical and sub-tropical deserts of Sahara in Africa, and of West Asia and Australia.
- These air masses are dry, hot and stable and do not extend beyond the source.
- They are dry throughout the year.

Maritime Tropical Air Masses (MT)

- The source regions of these air masses include the oceans in tropics and sub-tropics such as Mexican Gulf, the Pacific, and the Atlantic oceans.
- These air masses are **warm, humid, and unstable.**
- The weather during winter has mild temperatures, overcast skies with fog.
- During summer, the weather is characterized by high temperatures, high humidity, cumulous clouds, and convectional rainfall.

Fronts

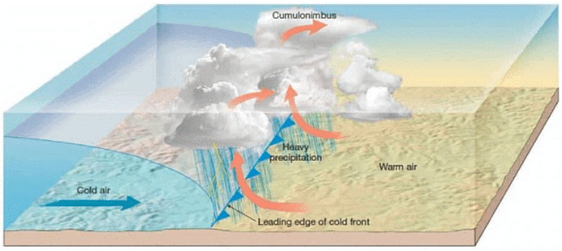
- Fronts refer to the boundaries that form between air masses with different temperatures. Although they are transition zones, the area of change, known as the frontal zone, can sometimes be quite distinct. Fronts typically occur in midlatitude regions (30° – 65° N and S) and are less common in tropical and polar areas.
- A front is a three-dimensional boundary zone that develops between two converging air masses with varying physical properties, such as temperature, humidity, and density. When these dissimilar air masses come into contact, they do not easily merge due to the effects of the converging atmospheric circulation, low diffusion coefficient, and low thermal conductivity.
- The concept of fronts was introduced by Norwegian meteorologists during World War I. They coined the term "front" as they believed the interaction between different air masses resembled a confrontation between opposing armies along a battlefront. As the more dominant air mass advances and displaces the other, some mixing occurs within the frontal zone. However, both air masses mostly maintain their separate identities.

Front Formation

- Front formation, also known as Frontogenesis, refers to the process in which two distinct air masses converge or come together, resulting in a battle between the two masses. On the other hand, Frontolysis is the process where one air mass overpowers the other, leading to the dissipation of the front.
- Frontogenesis is characterized by the merging of two different air masses, while Frontolysis involves one air mass dominating and overtaking the other. In the Northern Hemisphere, Frontogenesis occurs in an anticlockwise direction, while in the Southern Hemisphere, it occurs in a clockwise direction. This

difference in direction is due to the Coriolis effect, which is a result of the Earth's rotation.

- Mid-latitude cyclones, also known as temperate cyclones or extra-tropical cyclones, are weather phenomena that occur as a result of frontogenesis. These cyclones involve the interaction of air masses with different temperatures and densities, which leads to the formation of a front and the development of a cyclone.



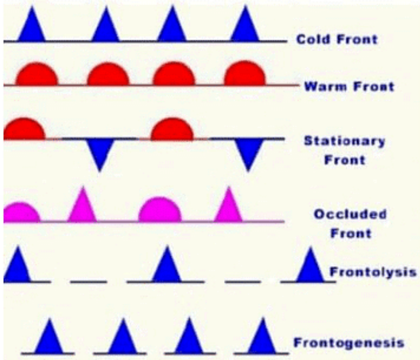
Characteristics of Fronts

The characteristics of fronts are influenced by various factors such as temperature, pressure, and wind patterns. Fronts are areas where two air masses with different temperatures meet, and these temperature differences play an important role in determining the thickness of the frontal zone. If the temperature contrast between the two air masses is higher, they are less likely to mix easily, resulting in a thinner front.

- In addition to temperature differences, pressure also changes suddenly across a front. This is because temperature and pressure are closely related, with changes in one often leading to changes in the other.
- Wind patterns are also affected by fronts, as wind movement is influenced by both the pressure gradient and the Coriolis force. This can result in a wind shift, which is defined as a change in wind direction of 45 degrees or more within a period of less than 15 minutes, with sustained wind speeds of at least 10 knots throughout the shift.
- Frontal activity is typically associated with cloud formation and precipitation due to the rising of warm air. When warm air ascends, it cools down as it expands, causing the water vapor within it to condense and form clouds. This process is known as adiabatic cooling, and the rate at which the temperature drops with increasing altitude is referred to as the adiabatic lapse rate. The latent heat of condensation is also released during this process, further contributing to cloud development.
- The intensity of precipitation that occurs along a front depends on the slope of the ascending air and the amount of water vapor present within it. A steeper slope of ascent and higher levels of water vapor will generally result in heavier precipitation. Overall, the characteristics of fronts are influenced by a combination of temperature, pressure, wind patterns, and moisture content, which all play a role in determining the weather associated with these meteorological phenomena.

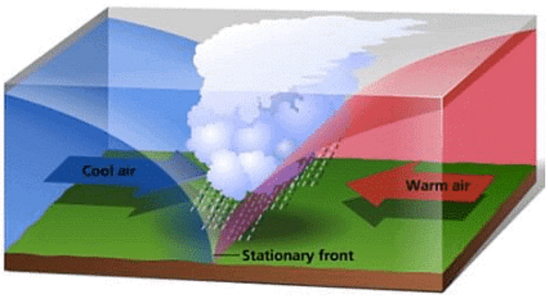
Classification of Fronts

- Based on the mechanism of frontogenesis and the associated weather, the fronts can be studied under the following types.



Stationary Front

- A stationary front occurs when the boundary between two air masses remains stationary, meaning that neither air mass can push against the other, resulting in a standstill.
- This happens when the wind movement on both sides of the front runs parallel to the front itself. Such a front is called a stationary front because the warm or cold front ceases to move.
- Once the boundary starts moving again, it will be classified as either a warm front or a cold front, depending on the air mass dynamics.



Weather along a stationary front

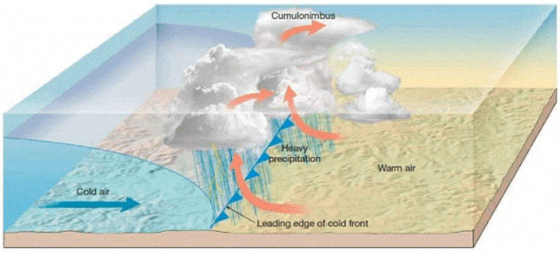
- Cumulonimbus clouds are created when warm air rises and cools, leading to the formation of these large, towering clouds. When warm air flows over a colder air

mass along a weather front, it results in frontal precipitation, which is a common weather phenomenon.

- When cyclones move along a stationary front, they can cause heavy rainfall, leading to significant flooding in the areas near the front. This can be a serious issue, especially if the front remains stationary for an extended period, allowing the cyclone to continuously produce heavy rainfall.

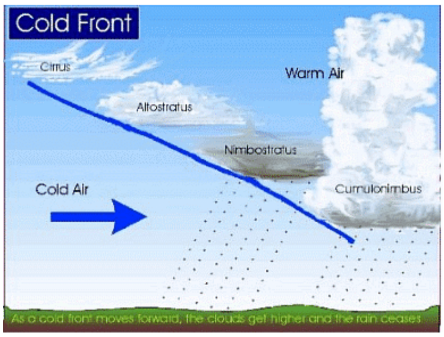
Cold Front

- A cold front occurs when a cold air mass overtakes and replaces a warm air mass, either by advancing into it or causing the warm air mass to retreat. In this scenario, the cold air mass is the dominant force, and the boundary between the two air masses is known as the cold front.
- Cold fronts tend to move at a faster pace than warm fronts, sometimes advancing at twice the speed. The process of frontolysis, which is the dissipation of the frontal boundary, starts when the warm air mass is entirely lifted away by the cold air mass.



Weather along a cold front

- The weather along such a front depends on a narrow band of cloudiness and precipitation.
- Severe storms can occur. During the summer months thunderstorms are common in warm sector.
- In some regions like USA tornadoes occur in warm sector.
- Produce sharper changes in weather. Temperatures can drop more than 15 degrees within the first hour.

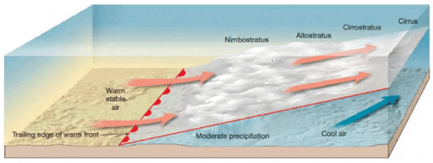


Cloud formation along a cold front

- The approach of a cold front is marked by increased wind activity in warm sector and the appearance of cirrus clouds, followed by lower, denser altocumulous and
- At actual front, dark nimbus and cumulonimbus clouds cause heavy showers. A cold front passes off rapidly, but the weather along it is violent.

Warm Front

- It is a sloping frontal surface along which active movement of warm air over cold air takes place (warm air mass is too weak to beat the cold air mass).
- Frontolysis (front dissipation) begin when the warm air mass makes way for cold air mass on the ground, i.e. when the warm air mass completely sits over the cold air mass.



Weather along a warm front

- As the warm air moves up the slope, it condenses and causes precipitation but, unlike a cold front, the temperature and wind direction changes are gradual.
- Such fronts cause moderate to gentle precipitation over a large area, over several hours.
- The passage of warm front is marked by rise in temperature, pressure and change in weather.

Clouds along a warm front

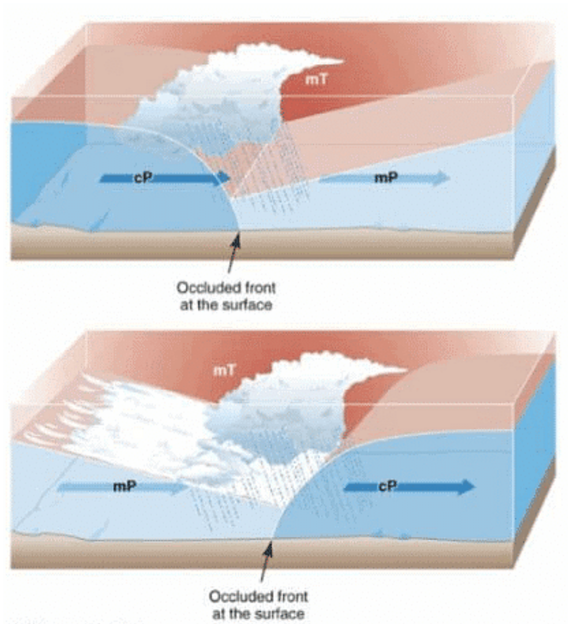
- With the approach, the hierarchy of clouds is—-cirrus, stratus and nimbus. [No cumulonimbus clouds as the gradient is gentle]
- Cirrostratus clouds ahead of the warm front create a halo around sun and moon.

Occluded Front

- Occlusion in meteorology refers to a phenomenon where the cold front of a rotating low-pressure system catches up to the warm

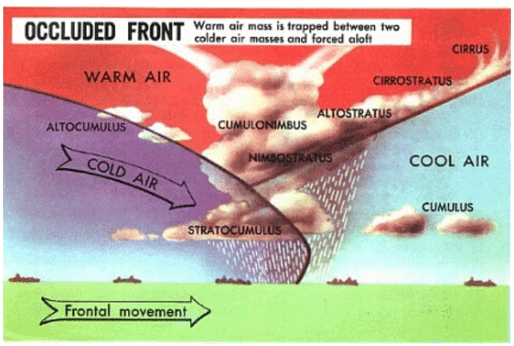
front, causing the warm air between them to be pushed upwards. This occurs when a cold air mass moves faster than a warm air mass and slides beneath it.

- As the warm sector decreases in size, the cold air mass eventually takes over the entire warm sector at ground level, leading to the process known as frontolysis. Consequently, an elongated and backward-swinging occluded front is formed, which can be classified as either a warm front type or cold front type occlusion.



Weather along an occluded front

- Weather along an occluded front is complex—a mixture of cold front type and warm front type weather. Such fronts are common in west Europe.
- The formation Mid-latitude cyclones [temperate cyclones or extra-tropical cyclones] involve the formation of occluded front.



Clouds along an occluded front

- A combination of clouds formed at cold front and warm front.
- Warm front clouds and cold front clouds are on opposite side of the occlusion.

Air Masses, Fronts, and Major Atmospheric Disturbances

- Atmospheric disturbances, which can cause both stormy and calm weather conditions, play a significant role in the Earth's general circulation. These disturbances share some common characteristics: they are smaller than the components of the general circulation, migratory, relatively short-lived, and produce relatively predictable weather conditions.
- There are several types of atmospheric disturbances, with the most important ones occurring in the midlatitudes and the tropics. In the midlatitudes, where polar and tropical air masses meet and most fronts occur, weather is very dynamic and changeable. The two most significant disturbances in this region are midlatitude cyclones and midlatitude anticyclones, which greatly impact the weather due to their size and frequency.
- In the tropics, weather is generally consistent and repetitive, with only occasional disturbances. The most significant of these tropical disturbances are tropical cyclones, also known as hurricanes when they intensify. Additionally, there are less dramatic disturbances called easterly waves that also occur in the tropics
- Localized severe weather, such as thunderstorms and tornadoes, can occur in various parts of the world. These short-lived and sometimes intense disturbances often develop in conjunction with other types of storms. Overall, understanding these atmospheric disturbances is crucial for predicting and managing weather patterns and their impacts on our daily lives.

Which of the following is NOT a factor that influences the characteristics of fronts? A. Temperature differences between air masses **B.** Pressure changes across the front **C.** Wind patterns near the front **D.** The altitude of the front

Conclusion

Air masses and fronts play a critical role in shaping global weather patterns and atmospheric disturbances. Forming over homogeneous surfaces, air masses acquire specific temperature and humidity characteristics, which influence

various weather phenomena when they interact with other air masses. Fronts, as boundaries between different air masses, are crucial in the formation of mid-latitude cyclones, storms, and other meteorological events. Understanding the dynamics of air masses, fronts, and atmospheric disturbances is essential for accurate weather prediction and preparedness, ultimately impacting various aspects of human life and the environment.

What is an air mass and why is it important in understanding weather patterns?

An air mass is a large body of air that has acquired specific characteristics in terms of temperature and humidity due to remaining over a homogeneous area for an extended period of time. Air masses play a crucial role in the global planetary wind system and are typically associated with specific wind belts. Understanding air masses helps us predict and manage weather patterns and their impacts on our daily lives.

What are the primary source regions for air masses?

The primary source regions for air masses are located in the subtropical high-pressure belts, which give rise to tropical air masses, and around the poles, which serve as the source for polar air masses.

What is a front in meteorology, and why is it significant?

A front is a three-dimensional boundary zone that develops between two converging air masses with varying physical properties, such as temperature, humidity, and density. Fronts typically occur in midlatitude regions and are less common in tropical and polar areas. Fronts are significant because they influence factors such as temperature distribution, moisture content, and atmospheric stability, which all play a role in determining the weather associated with these meteorological phenomena.

How are fronts classified, and what are some examples?

Fronts are classified based on the mechanism of frontogenesis (front formation) and the associated weather. Some examples of fronts include stationary fronts, cold fronts, warm fronts, and occluded fronts. Each type of front has specific characteristics and weather conditions associated with it.

What are the main types of atmospheric disturbances, and how do they affect weather?

The main types of atmospheric disturbances include midlatitude cyclones and anticyclones, tropical cyclones (also known as hurricanes), and localized severe weather such as thunderstorms and tornadoes. These disturbances can cause both stormy and calm weather conditions and play a significant role in the Earth's general circulation. Understanding these atmospheric disturbances is essential for predicting and managing weather patterns and their impacts on our daily lives.

1. What are air masses and how are they classified?

Ans. Air masses are large bodies of air with similar temperature and humidity characteristics. They are classified based on their source region and temperature characteristics. There are four main types of air masses: continental polar (cP), maritime polar (mP), continental tropical (cT), and maritime tropical (mT).

2. What are the characteristics of fronts?

Ans. Fronts are boundaries between air masses with different temperature, humidity, and density characteristics. There are four main types of fronts: cold fronts, warm fronts, stationary fronts, and occluded fronts. Cold fronts bring colder air and often result in thunderstorms and heavy precipitation. Warm fronts bring warmer air and are associated with steady precipitation. Stationary fronts occur when two air masses meet but neither advances, resulting in prolonged periods of precipitation. Occluded fronts occur when a cold front overtakes a warm front, leading to complex weather patterns.

3. How do air masses, fronts, and major atmospheric disturbances interact?

Ans. Air masses and fronts play a crucial role in the development of major atmospheric disturbances such as cyclones and anticyclones. When air masses of different characteristics collide at fronts, they can trigger the formation of low-pressure systems like cyclones, which are associated with stormy weather. On the other hand, when air masses sink and diverge, they can create high-pressure systems like anticyclones, which are associated with fair weather.

4. What are some major atmospheric disturbances that can occur due to air masses and fronts?

Ans. Some major atmospheric disturbances that can occur due to air masses and fronts include hurricanes, tornadoes, and thunderstorms. Hurricanes are large rotating storms that form over warm ocean waters and are fueled by maritime tropical air masses. Tornadoes are violent rotating columns of air that form in severe thunderstorms and are often associated with cold fronts. Thunderstorms are intense convective storms that can occur along any type of front and are characterized by lightning, thunder, and heavy rainfall.

5. What are some frequently asked questions about air masses and fronts?

Ans. Some frequently asked questions about air masses and fronts include: - How do air masses form? - What causes fronts to form? - How do air masses and fronts influence weather patterns? - How do meteorologists track and predict the movement of air masses and fronts? - How do air masses and fronts affect temperature and precipitation?

Koppen’s , Thornwaite’s & Trewar Tha’s Classification of World’s Climate

Koppen Climate Classification System

- **The Koppen Climate Classification System** is the most widely used modern climate classification system. It was developed by Wladimir Köppen, a Russian-German climatologist, who sought to classify the world's climates by examining the close relationship between vegetation and climate in different regions. His goal was to create a chart with formulas and notations that would accurately define climatic boundaries based on the existing vegetation in the area.
- In simpler terms, Köppen studied the trees and plants in various regions and determined the relationship between the vegetation and the climate of those areas. Using this information, he established a chart that categorized different climates into groups, along with their defining traits.
- To achieve this, Köppen selected specific temperature and precipitation values, relating them to the distribution of vegetation. He then used these values to classify the climates. The resulting system classifies the world's

climates using capital letters - A, B, C, D, E, and H. These categories are further subdivided into types and subdivisions using lowercase letters - a, b, c, d, h, f, m, w, k, and s.

- Before delving deeper into the Koppen Climate Classification System, it's essential to understand the difference between weather and climate.

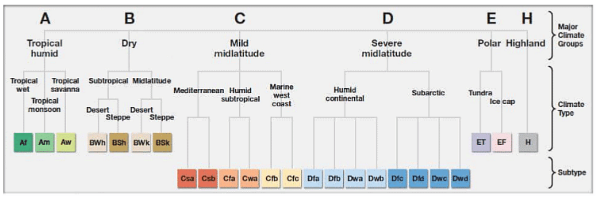
Differences between weather and climate

	Climate	Weather
Definition	Describes the average conditions expected at a **specific place at a given time (considerable time)**. A region's climate is generated by the climate system, which has five components: atmosphere, hydrosphere, cryosphere, land surface, and biosphere.	Describes the atmospheric conditions at a specific **place at a specific point in time**. Weather generally refers to day-to-day temperature and precipitation activity
Components	Climate may include precipitation, temperature, humidity, sunshine, wind velocity, phenomena such as fog, frost, and hail storms over a long period of time.	Weather includes sunshine, rain, cloud cover, winds, hail, snow, sleet, freezing rain, flooding, blizzards, ice storms, thunderstorms, steady rains from a cold front or warm front, excessive heat, heat waves and more
Forecast	By aggregates of weather statistics over periods of 30 years	By collecting meteorological data, like air temperature, pressure, humidity, solar radiation, wind speeds and direction etc.
Determining factors	Aggregating weather statistics over periods of 30 years ("climate normals").	Real-time measurements of atmospheric pressure, temperature, wind speed and direction, humidity, precipitation, cloud cover, and other variables
About	Climate is defined as statistical weather information that describes the variation of weather at a given place for a specified interval.	Weather is the day-to-day state of the atmosphere, and its short-term (minutes to weeks) variation
Time period	Measured over a long period	Measured for short term
Study	Climatology	Meteorology

Wladimir Köppen (1846-1940) was a German climatologist of Russian origin who also had a keen interest in botany. He developed a climate classification system, with the first version introduced in 1918. Throughout his life, Köppen continued to make adjustments and improvements to the system, with the final version published in 1936.

The modified Köppen classification system comprises five primary climate groups, labeled A, B, C, D, and E. These groups are further divided into a total of 14 distinct climate types, as well as an additional category for highland (H) climates.

Which climate group in the Trewartha Climate Classification system is characterized by low rainfall and a significant difference between the amount of moisture lost and gained? A. Group A: Tropical climates **B.** Group B: Dry climates **C.** Group C: Subtropical climates **D.** Group D: Temperate and continental climates



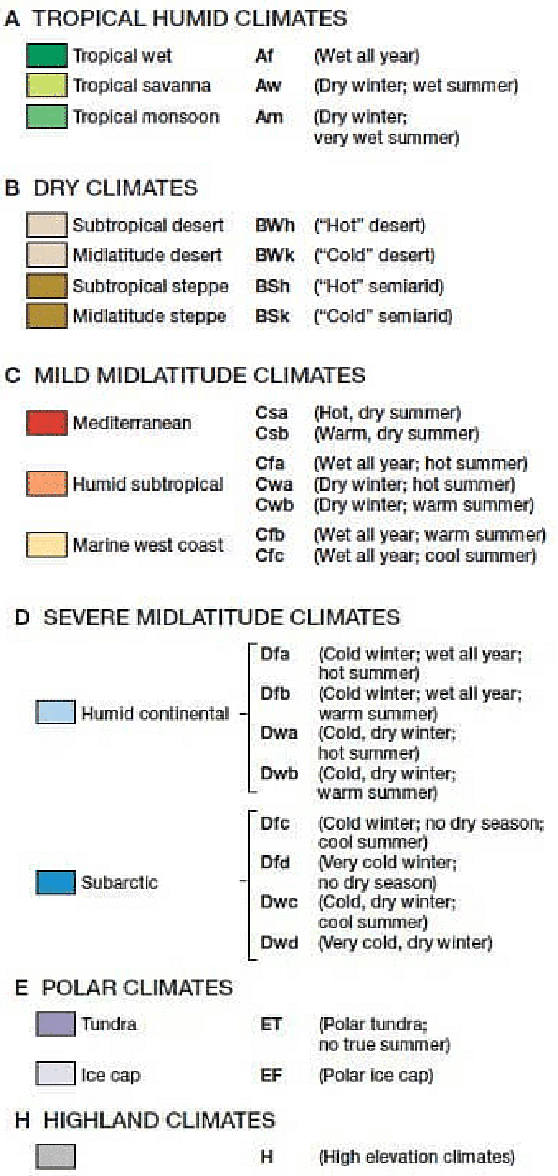
Climate Groups According to Koeppen

Group	Characteristics
A - Tropical	Average temperature of the coldest month is 18° C or higher
B - Dry Climates	Potential evaporation exceeds precipitation
C - Warm Temperate	The average temperature of the coldest month of the (Mid-latitude) climates years is higher than minus 3°C but below 18°C
D - Cold Snow Forest Climates	The average temperature of the coldest month is minus 3° C or below
E - Cold Climates	Average temperature for all months is below 10° C
H - High Land	Cold due to elevation

Climatic Types According to Koeppen

Group	Type	Letter Code	Characteristics
A-Tropical Humid Climate	Tropical wet	Af	No dry season
	Tropical monsoon	Am	Monsoonal, short dry season
	Tropical wet and dry	Aw	Winter dry season
B-Dry Climate	Subtropical steppe	BSh	Low-latitude semi arid or dry
	Subtropical desert	BWh	Low-latitude arid or dry
	Mid-latitude steppe	BSk	Mid-latitude semi arid or dry
	Mid-latitude desert	BWk	Mid-latitude arid or dry
C-Warm temperate (Mid-latitude) Climates	Humid subtropical	Cfa	No dry season, warm summer
	Mediterranean	Cs	Dry hot summer
	Marine west coast	Cfb	No dry season, warm and cool summer
D-Cold Snow-forest Climates	Humid continental	Df	No dry season, severe winter
	Subarctic	Dw	Winter dry and very severe
E-Cold Climates	Tundra	ET	No true summer
	Polar ice cap	EF	Perennial ice
H-Highland	Highland	H	Highland with snow cover

1. **Koeppen recognized five major climatic groups, four of them are based on temperature and one on precipitation.**
2. The capital letters:
   - **A, C, D, and E delineate humid climates and**
   - **B dry climates**
3. The climatic groups are subdivided into types, designated by small letters, based on seasonality of precipitation and temperature characteristics.
4. The seasons of dryness are indicated by the small letters: **f, m, w, and s**, where
   - **f – no dry season,**
   - **m – monsoon climate,**
   - **w – winter dry season and**
   - **s – summer dry season.**
5. The above mentioned major climatic types are further subdivided depending upon the seasonal distribution of rainfall or degree of dryness or cold.
   - **a: hot summer, the average temperature of the warmest month over 22°C**
   - **c: cool summer, the average temperature of the warmest month under 22°C**
   - **f: no dry season**
   - **w: the dry season in winter**
   - **s: the dry season in summer**
   - **g: Gange's type of annual march of temperature; hottest month comes before the solstice and the summer rainy season.**
   - **h: average annual temperature under 18°C**
   - **m (monsoon): short dry season.**
6. The capital letters S and W are employed to designate the two subdivisions of dry climate
   - **semi-arid or Steppe (S) and**
   - **arid or desert (W).**
7. Capital letters T and F are similarly used to designate the two subdivisions of polar climate
   - **tundra (T) and**
   - **icecap (F).**



Thornthwaite Climatic Classification

C. W. Thornthwaite, an American climatologist, first introduced his climatic classification system for North America in 1931 when he published a climatic map of the continent. He later expanded this classification system to cover global climates and presented his complete scheme in 1933. Thornthwaite further revised and modified his system, releasing a second version in 1948, which included the concept of potential evapotranspiration. His classification system is considered complex and empirical.

Initially, Thornthwaite's classification scheme resembled Köppen's system, as both believed that vegetation is an indicator of climate type. Thornthwaite's system is primarily based on two key factors: precipitation effectiveness (P/E, where P represents total monthly precipitation and E represents total monthly evaporation) and temperature efficiency.
Using these two indicators, Thornthwaite divided the world into five humidity regions:

A: Very Humid Rainforest - regions characterized by abundant rainfall and high humidity, supporting lush vegetation.
B: Humid Forest - regions with significant rainfall and humidity, enabling the growth of dense forests.
C: Semi-Humid Grassland - areas with moderate rainfall and humidity levels, resulting in grassy landscapes rather than dense forests.
D: Semi-Dry Steppe - regions with limited rainfall and lower humidity, leading to sparse vegetation and steppe landscapes.
E: Dry Desert - areas with extremely low rainfall and humidity, resulting in arid desert environments with minimal vegetation.
Each region had its own special type of vegetation as shown in the table below:

Sr. No.	Humidity Region	Special type of Vegetation
A	Very Humid	Rain Forest
B	Humid	Forest
C	Semi Humid	Grassland
D	Semi Dry	Steppe
E	Dry	Desert

Design of Thornthwaite Climatic Classification
Thornthwaite's design of climate classification is a combination of **three letter alphabets.**

- **The first** alphabet used in the major climatic classification is any one of the **English capital letters from A to E.**
- **The second** letter used in the climatic classification is also an **English capital alphabet superscript with a dash.** It denotes thermal provinces.
- **The third letter** in a combination of **alphabets is denoted by a set of 8 small English alphabets.**

Precipitation effectiveness

1. Plants' growth is not only dependent on precipitation but precipitation effectiveness.
2. Precipitation effectiveness P/E ratio=total monthly precipitation/ Evapotranspiration P/E index= sum of 12 month P/E ratio.
3. **Based on the P/E index, Thornthwaite classified five humidity region:**
   - **A:** (P/E index>128) – Wet-Rainforest.
   - **B:** (P/E Index 64 to 127) – Humid-Forest
   - **C:** (P/E index 32 to 63) – Subhumid-Grassland.
   - **D:** (P/E index 16-32) – Semi Arid-Steppe
   - **E:** (P/E index less than 16) – Arid-Desert

On the basis of precipitation effectiveness, thermal efficiency, and seasonal distribution of rainfall there may be 120 probable

combinations and hence climatic types on the theoretical ground but he depicted only 32 climatic types on the world.

- On the basis of the distribution of seasonal rainfall the above types of humidity regions were further divided into the following subdivisions:
  r = Heavy rainfall in all seasons
  s = Scarcity of rainfall in the summer season
  w = Scarcity of rainfall in the winter season
  d = Scarcity of rainfall in all seasons
  Aridity index for humid climates
  (i) Moisture deficit acute during winter = w2
  (ii) Moisture deficit acute during summer =s2
  Humidity index for arid climates
  (i) Moisture surplus abundant during winter =s2
  (ii) Moisture surplus abundant during summer = w2

Letter	Humidity province	Vegetation	P-E index
A	Wet	Rainforest	> 127
B	Humid	Forest	64-127
C	Subhumid	Grassland	32-63
D	Semiarid	Steppe	16-31
E	Arid	Desert	< 16

Temperature efficiency

1. Temperature efficiency is calculated mean average temperature of through years.
2. Based on Temperature efficiency – Thornthwaite has divided the world into six thermal provinces. They are expressed as:
   - **A'** — tropical: (T/E index more than 128).
   - **B'** — Subtropical: (T/E index 64-127).
   - **C'** — Temperate: (T/E index 32 – 63)
   - **D'** — Taiga: (T/E index 16-31)
   - **E'** — Tundra: (T/E index 1-15).
   - **F'** — Frost: (T/E index 0).

Thornthwait was being criticized for making climatic classification complex. To make it simple, Thornthwait gave the **evapotranspiration concept to derive a climatic region in 1948.**

Evapotranspiration: Combined, **evaporation from the soil and transpiration from vegetation** is called Evapotranspiration.

- The modified Thornthwaite system (1948) is a climatic classification system that is based on the concept of potential evapotranspiration (PE), which estimates the water use of plants with an unlimited water supply. This system differs from Thornthwaite's 1931 classification, where he focused on vegetation instead of potential evapotranspiration.
- In this updated system, Thornthwaite used three indices to classify climates: precipitation effectiveness, thermal efficiency, and seasonal distribution of precipitation. However, these indices were used differently than in his earlier classification.
- Potential evapotranspiration (PE) is an important concept in this system as it represents the amount of water and heat transferred to the atmosphere from soils and vegetation (through evaporation and transpiration). This process is directly related to the amount of energy received from the sun, making it an index of thermal efficiency and water loss.
- In summary, the modified Thornthwaite system (1948) is a climatic classification scheme that focuses on potential evapotranspiration as a key concept, using it as an index of thermal efficiency and water loss. This system relies on three indices – precipitation effectiveness, thermal efficiency, and seasonal distribution of precipitation – to classify climates, with a unique emphasis on potential evapotranspiration as a critical factor.

Index in modified method

- **Aridity Index (Ia)**
- **Humidity Index (Ih)**
- **Soil Moisture Index (Im)**

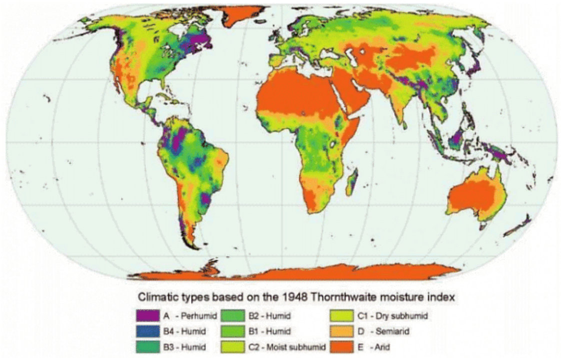
if: PET >Precipitation = Soil Moisture 0/-ve
if: Precipitation > PET = Soil Moisture +ve

- **Moist Climate determined by Aridity Index (variability in summer and winter)**
- **Dry climate determined by Moisture Index**

Symbol	Moist Climate (A, B, C_2)	Aridity Index (I_a)
r	Little or no moisture deficit	0-16.7
s	Summer deficit (normal)	16.7-33.3
w	Winter deficit (normal)	16.7-33.3
s_2	Summer deficit (acute)	33.3+
w_2	Winter deficit (acute)	33.3+
Symbol	Dry Climate (C_1, D, E)	Humidity Index (I_h)
d	Winter surplus negligible	0-10
s	Winter moisture surplus (normal)	10-20
w	Summer moisture surplus (normal)	10-20
s_2	Winter moisture surplus (abundant)	20+
w_2	Summer moisture surplus (abundant)	20+

Humidity Provinces	Thermal Efficiency Index
A' (Megathermal)	Over 114
B'_4 (Mesothermal)	99.7 to 114
B'_3 (Mesothermal)	60 to 80
B'_2 (Mesothermal)	40 to 60
B'_1 (Mesothermal)	57 to 71.2
C'_2 (Microthermal)	0 to 20
C'_1 (Microthermal)	-20 to 0
D' (Tundra)	-40 to -20
E' (Frost)	-60 to -40

Humidity Provinces	Moisture Index (I_m)
A (Perhumid)	Over 100
B_4 (Humid)	80-100
B_3 (Humid)	60-80
B_2 (Humid)	40-60
B_1 (Humid)	20-40
C_2 (Moist sub-humid)	0 to 20
C_1 (Dry sub-humid)	-20 to 0
D (Semi-arid)	-40 to -20
E (Arid)	-60 to -40



Criticism of the Thornthwaite Climatic Classification

Thornthwaite's Climatic Classification has made significant qualitative improvements in categorizing global climates. However, the system has faced several criticisms due to various shortcomings in its approach and applicability.

- One of the main criticisms is that Thornthwaite's classification does not take into account factors such as prevailing winds, relative humidity, air pressure, and air masses, which play a crucial role in determining the climate of a region. Additionally, the system fails to consider the influence of relief and the position of the sun concerning the incidence of solar radiation on Earth.
- While the classification has been found to be satisfactory in North America, where vegetation boundaries align well with specific precipitation-to-evapotranspiration (P/E) values, it falls short in accurately classifying tropical and semi-arid regions. This is partly due to the complexity of calculating soil moisture balance for different natural regions and vegetation zones, which can lead to a lack of clarity in the classification system.
- Another significant issue is the limited availability of data on meteorological variables, both in terms of time and geographical coverage. This data scarcity poses a challenge in applying Thornthwaite's classification system to various regions worldwide.
- Furthermore, the complex nature of the classification system has made it less widely used and of limited application. Researchers and practitioners often find it difficult to navigate and apply the system to analyze and classify various climatic conditions.
- Lastly, Thornthwaite's Climatic Classification does not address contemporary issues such as global warming, climate change, and the increasing frequency of extreme weather events. As these issues become increasingly important in understanding and managing our global climate, the limitations of the Thornthwaite system become more apparent.

In conclusion, although Thornthwaite's Climatic Classification has made strides in improving the categorization of world climates, it still faces several criticisms and limitations that need to be addressed for it to be more widely used and applicable in today's changing climate.

Thornthwaite climatic division of India

The following are the climatic division of India as per the **Thornthwaite concept of Evapotranspiration.**

1. **Per Humid(A) region of India**
   - Western Ghats
   - Most parts of the NorthEastern States
2. **Humid(B) region of India**
   - Adjoining region of the Perhumid region
3. **Moist Sub Humid(C1) climatic region**
   - Narrow belt Adjoining region of the humid region of Western Ghats.
   - Eastern India comprises of West Bengal and Orissa
4. **Dry Sub Humid(C2) regions**
   - Northern Narrow belt of the Ganga basin.
   - Part of Uttar Pradesh, Bihar, MP, Chhattisgarh, Jharkhand
   - Western Maharastra and Southern Gujarat
5. **Semi-Arid(D) climatic region**
   - Part of Punjab and Haryana
   - Eastern part of Rajasthan, Maharashtra, Karnataka, Lenangna
   - Western Pat of Tamilnadu.
6. **Arid climatic(E) region of India:**
   - Western Rajasthan
   - Western Himalayan
   - Rainshadow zone of western Ghats

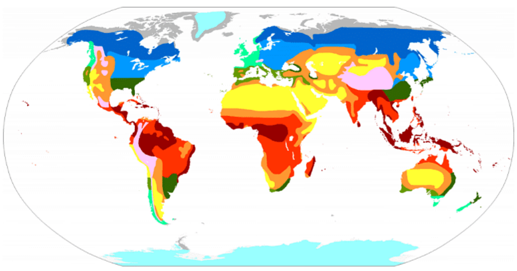
Trewartha Climatic Classification

The Trewartha climate classification is a system for categorizing climates, developed by American geographer Glenn Thomas Trewartha in 1966. This classification is considered a modified version of the Koeppen system and aims to be simpler and more explanatory. Trewartha's approach combines elements from both empirical and genetic classification schemes, making it more accessible and easier to understand.

- Trewartha was aware that the classification systems of Koeppen and Thornthwaite, which were based on specific statistical parameters of weather elements, were complex and difficult to use. As a result, he chose to focus on a limited number of primary climate types in his classification system. Trewartha's classification is primarily based on two fundamental weather elements: temperature and precipitation. Additionally, he considered the effects of land and water surfaces on the climate of a particular area.
- Trewartha's climate classification system includes seven climate groups, six of which (A, C, D, E, F, and H) are based on temperature criteria. The overall goal of this classification system is to provide a more straightforward and comprehensible method for categorizing and understanding the world's various climates.
- Group A: Tropical climates
- Group C: Subtropical climates
- Group D: Temperate and continental climates
- Group E: Boreal climates
- Group F: Polar climates
- Group H: Highland climates

the seventh- B: is the dry group based on precipitation.

- Group B: Dry **(arid and semi-arid) climates**



Trewartha climate types for the world

Climatic Groups Based on Temperature Criteria
Group A

- This is the **tropical climate group.**
- This type of climate is **found in the low latitudes on each side of the equator** in an irregular belt **20° to 40° wide.**
- There is – **no winter season** in-this climatic-group.
- **Temperature is uniformly high throughout the year with adequate annual rainfall.**
- In **marine areas, the average temperature for the coldest month is around 18°C to 20°G.**
- This climatic group is subdivided into **two climatic types:**

(i) Ar
(ii) Aw

1. Ar

- Ar. is a **tropical wet climate.**
- This type of climate is characterized by **less than two dry months.**
- The climate is under the influence of the intertropical convergence zone and the equatorial westerlies.
- The belt is distinguished by constant low pressure and is **also known as the tropical rainforest.**

2. Aw

- Aw is a **tropical wet-and-dry climate.**
- At the time of the low sun, two months are usually dry.
- The climatic regions are dominated by the **dry trade winds or subtropical anticyclones.**
- During the high sun period, the equatorial westerlies and intertropical convergence control the weather.
- The duration of the dry season is usually longer than that of the wet season.
- The **temperature remains uniformly high** in this type of climate.

Group C

- This category encompasses **subtropical climate with temperatures above 10 °C** for only **eight or more months.**
- **Frosts occur occasionally in continental parts, but the marine locations remain frostless,**

On the basis of the seasonal distribution of precipitation, the subtropical climate is further classified into **two climatic types**

- **Cfw**
- **Cs**

1. **Cfw**
   - Cfw. is a **sub-tropical humid climate.**
   - **This type of climate is found on the eastern side of continents.**
   - It has no distinct dry season and rains fall throughout the year.
   - During the summer season, **this type of climate comes under the influence of unstable air in the western end of a subtropical anticyclone.**
   - But & ring winter, the climate is influenced by temperate cyclones.

2. **Cs**
   - Cs. is a **sub-tropical dry summer climate.**
   - It is characterized by a moderate to scanty amount of precipitation.
   - **Winter is the rainy season,** while summers are nearly or completely dry.
   - This climate type represents a transition zone between the tropical dry climates towards the equator and the temperate climates towards the poles.
   - The **average annual precipitation is less than 890 mm (35 inches).**

Group D

- This group represents **temperate climates.**
- The climatic group is **also known as the micro-thermal climatic type.**
- The average temperature is around **10 °C** for 4 to 8 months.
- This type of climate is **found in the middle latitudes** between the sub-tropical and boreal climates.
- The two types of climate that are included in the temperate group of humid climates are:
  (i) Do
  (ii) Dc

1. **Do**
   - **Do. is temperate marine climate.**
   - With mild winters, the average temperature for all the 12 months is 0 °C or above.
   - A **humid climate with adequate precipitation at all seasons**, it is found on the western windward side of the continents in the temperate zone.
2. **Dc**
   - **Dc. is a temperate continental climate** found in the continental interiors of the middle-latitude continents.
   - The **climate is basically land-controlled.**
   - The **climatic type is characterized by severe winters and summers.**
   - Annual temperature ranges are, therefore, high throughout this climate, Cold waves, heat waves, blizzards, and heavy downpours are all yearly events in this category, of climate.
   - Precipitation occurs throughout the year with maximum concentration during summers.

Group E

- The group represents **sub-arctic or boreal climate found in the higher middle latitudes.**
- Super-continental in temperate features, here the summers are short and comparatively cool.
- The winters are, however, long and very cold with a very short frost-free season.
- The average temperature hovers around **10 °C** for one to three months during the year.
- The rest of the year has an **average temperature below 10 °C.**
- These regions are characterized by the lowest annual means of temperature for any part of the earth.
- Even though boreal climates are classified as humid, annual precipitation is comparatively very less.
- **Precipitation occurs throughout the year, most during the warmer months when the amount of water vapour present in the air is highest.**
- Because of the severity of climate, the population is sparse.

Group F

- The group consists of **polar climate found in the high latitudes.**
- The climate is confined to the northern hemisphere only.
- The average temperature in this type of climate seldom exceeds -1O °C.
- There is no summer season.

The polar climates are classified into the following **two climatic types:**

1. **Ft**
   - **Ft. is Tundra climate found only in the northern hemisphere,** where it occupies the coastal sides of the Arctic Ocean, and many Arctic islands and ice-free shores of northern Iceland and southern Greenland.
   - No tundra climate is found in the southern hemisphere because of the complete absence of extensive land areas.
   - The Tundra region, essentially a region of grasses, mosses, and lichen, is characterized by the absence of trees. The average temperature of the warmest month is recorded between 0 °C and 10 °C.
2. **Fi**
   - **Fi. is an ice-cap climate** in which the average temperature for all the months is below freezing.

- There is no vegetation of any kind. The **land is permanently covered with ice and snow.**
- The climate is exclusively confined to the ice-caps of **Greenland and Antarctica.**

Group H

- The group **represents highland climates** in which altitude plays a role in determining climate classification.
- The temperature under normal conditions decreases with altitude, with the summit area of a mountain being always cooler than its base.
- Windward slopes force the incoming air to rise up with the resultant condensation, cloud formation, and precipitation.
- The leeward slopes are characterized by descending air which is warmed up and produces little precipitation.

Trewartha says there is no such thing as a highland type of climate because various types of local climates exist in every significant mountain range. There are no typical temperature and rainfall regimes in the highland climates.
Climate Group based on Precipitation Criteria:
Group B

- This climatic group represents a dry environment, which is primarily defined by its low precipitation levels. The main characteristic of a dry climate is that the moisture lost through evapotranspiration significantly exceeds the annual water gained from precipitation.
- In a dry climate, the weather is typically clear and calm, with a dry atmosphere leading to larger temperature fluctuations throughout the year compared to other latitudes. These regions experience low rainfall, high potential evaporation, abundant sunshine, and minimal cloud cover, all factors that contribute to the classification of a Group B climate.
- In simpler terms, a dry climate is characterized by low rainfall and a significant difference between the amount of moisture lost and gained, resulting in a harsh and arid environment with extreme temperature variations.

They are further classified into **two climatic groups.**

- **BW:** BW is an **arid or desert type** of climate.
- **BS:** BS is a **semi-arid or steppe type** of classification.

BW and BS are further classified into the following subdivisions on the basis of temperature:

- **BWh:** BWh is **tropical-subtropical hot deserts;**
- **BWK:** BWK is **temperate boreal cold deserts;**
- **BSh:** BSh is **tropical-boreal steppes; and**
- **BSk:** BSk is **temperate-boreal and cold.**

The BWh and BWK climates are constantly dry and are under the influence of subtropical high and dry trades.
The BWh type of condition lasts for 8 months or more with an average temperature over 10 °C while the BWK lasts fewer than 8 months with an average temperature above 10 °C.
The BSh is characterized by a short moist season and is greatly influenced by subtropical high and dry trades.
The BSK type of climate receives most of its major annual precipitation during the warmer season.

Which index is introduced by Thornthwaite to make his climatic classification system simpler in the modified version of 1948?
A. Aridity Index **B.** Humidity Index **C.** Potential Evapotranspiration (PE) **D.** Temperature Efficiency

Trewartha Climatic Classification of India

The Trewartha Climatic Classification system is a modified version of Köppen's classification, and it provides a fairly accurate representation of India's vegetation, agricultural, and geographical regions. In this system, four primary climatic categories (A, B, C, and H) are identified, which are further divided into seven distinct climatic types. This classification helps in better understanding the diverse climate patterns found across India.

They are as follows:

1. **A: Tropical Rainy Climatic Group**
   - Am—Tropical Monsoon
   - Aw—Tropical Savannah
2. **B: Dry Climatic Group**
   - BS—Tropical Steppe (semi-arid)
   - Bsh—Sub-Tropical Steppe
   - Bwh—Sub-Tropical Desert
3. **C: Humid Mesothermal Climatic Group**
   - Caw—Sub-Tropical Humid (Dry Winters)
4. **H: Mountain Climate**

The climatic letters **A, B, C, and H stand for the major groups of climate** and the other letters designate the sub-divisions of major groups.

- **A stands for the tropical rainy climate** with persistently high temperature which is not less than 18° C in the coolest month.
- **B is a dry climate** of those regions where the rate of evaporation is more than the moisture received from precipitation.
- **C represents humid sub-tropical or humid mesothermal climate.'** The temperature of the coldest month is between 18° C and 0° C.
- **a** – indicates **hot summers** with the warmest month having over 22° C temperature.
- **h** – is used when the **mean annual temperature is 18° C.**
- **m** – stands for **heavy but seasonal monsoon rainfall;** the dry period is very short.
- **s** – means **steppe or semi-arid climate.**
- **w** – stands for a **desert.**

The **tropical monsoon type of climate (Am) is found over the Western Ghats, western Nagaland, and Tripura.**

- The mean maximum and minimum temperatures here are 27° C and 18° C respectively.
- This region receives an **annual rainfall of 250 cm.**

The **tropical savannah climate (Aw) covers almost the whole of Deccan Plateau except a narrow strip of the rain-shadow area in the east of the Western Ghats, north-eastern Guajrat, southern Madhya Pradesh, southern Bihar, Orissa, Andhra Pradesh and Tamil Nadu.**

- This region receives, and an **annual rainfall of 100 cm** and the mean maximum temperature here is 45° C and the mean minimum temperature is 18° C.

The **tropical steppe (semi-arid) type of climate (BS) covers interior Karnataka, central Maharashtra, western Andhra Pradesh, and interior Tamil Nadu.**

- This region receives an **annual rainfall of less than 75 cm** and the mean maximum and means minimum temperatures here are 32° C and 23° C respectively.

The **sub-tropical steppe (Bsh) type covers an area from Punjab to Kachchh**, which is characterized by an **annual rainfall that fluctuates between 50 cm and 75 cm.**

- The mean maximum and mean minimum temperatures here are 46° C and 6° to 10° C respectively.

The **sub-tropical desert type of climate (Bwh) prevails over western Rajasthan and Kachchh.**

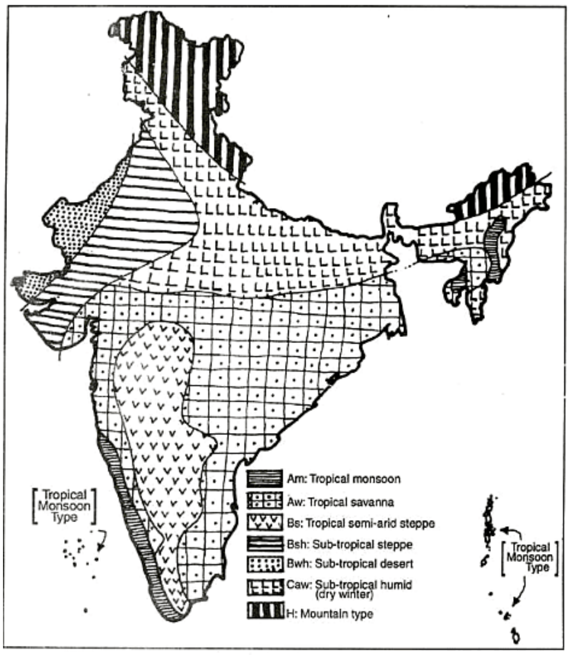
- This area receives a **low annual rainfall of 12.5 cm** and the mean maximum and **mean minimum temperatures here are 48° C and 12° C respectively.**

The **sub-tropical humid (dry winters) type of climate (Caw) covers the Punjab foothills, Uttar Pradesh, Bihar, West Bengal, Assam, and Arunachal Pradesh.**

- The annual **rainfall varies here from 62.5 cm** in the plains to up to 250 cm in the east. The mean maximum and minimum temperatures here are 46° C and 10° C respectively.

The **mountain type of climate (H) prevails in mountain areas of Kashmir and Arunachal Pradesh.**

- The northern slopes receive a **low rainfall of 8-10 cm annually** due to the rain-shadow effect, while the southern slopes receive 250 cm rainfall.
- The mean maximum temperatures vary between 10° C and 15° C and the **mean minimum temperatures go below zero.**



Conclusion

The Koppen, Thornthwaite, and Trewartha climate classification systems are essential tools for understanding and categorizing the world's diverse climates. Each system has its unique

approach and focuses on different aspects of climate, such as temperature, precipitation, and vegetation. While these systems have their limitations and criticisms, they provide a valuable foundation for studying climate patterns and their impact on human activities, agriculture, and ecosystems. Specifically, in India, these classifications help in understanding the diverse climate patterns and their influences on the country's vegetation, agriculture, and geography.

What is the Koppen Climate Classification System?

The Koppen Climate Classification System is the most widely used modern climate classification system, developed by Russian-German climatologist Wladimir Köppen. It aims to classify the world's climates based on the relationship between vegetation and climate in different regions. The system uses capital letters (A, B, C, D, E, and H) to categorize climates and further subdivides them using lowercase letters (a, b, c, d, h, f, m, w, k, and s).

What is the difference between Thornthwaite's Climatic Classification and Köppen's Climatic Classification?

Thornthwaite's Climatic Classification is based on precipitation effectiveness and temperature efficiency, using these factors to divide the world into five humidity regions. Köppen's Climatic Classification, on the other hand, focuses on specific temperature and precipitation values related to vegetation distribution to classify climates. Thornthwaite's system is considered more complex and empirical, while Köppen's system is more widely used and understood.

What is potential evapotranspiration and why is it important in Thornthwaite's modified classification system?

Potential evapotranspiration (PE) is an estimate of the water use of plants with an unlimited water supply, representing the amount of water and heat transferred to the atmosphere from soils and vegetation through evaporation and transpiration. PE is directly related to the amount of energy received from the sun, making it an index of thermal efficiency and water loss. In Thornthwaite's modified classification system, PE is used as a key concept to classify climates based on precipitation effectiveness, thermal efficiency, and seasonal distribution of precipitation.

What are the main criticisms of the Thornthwaite Climatic Classification system?

The main criticisms of the Thornthwaite Climatic Classification system include its failure to consider factors such as prevailing winds, relative humidity, air pressure, and air masses, as well as the influence of relief and the position of the sun concerning solar radiation. The system is also considered complex and difficult to use, with limited applicability in tropical and semi-arid regions. Additionally, it does not address contemporary issues such as global warming, climate change, and the increasing frequency of extreme weather events.

How does the Trewartha Climatic Classification system differ from the Köppen and Thornthwaite systems?

The Trewartha Climatic Classification system is a modified version of the Köppen system, aiming to be simpler and more explanatory. It combines elements from both empirical and genetic classification schemes, making it more accessible and easier to understand. Trewartha's classification is primarily based on temperature and precipitation, and it considers the effects of land and water surfaces on the climate of a particular area. This system includes seven climate groups (A, B, C, D, E, F, and H), with six groups based on temperature criteria and one group based on precipitation.

1. What is the Koppen Climate Classification System?

The Koppen Climate Classification System is a widely used system for classifying the world's climates based on the annual and monthly averages of temperature and precipitation. It was developed by German climatologist Wladimir Koppen in the early 20th century. The system divides climates into five main groups (tropical, dry, temperate, continental, and polar) and further subgroups based on variations in temperature and precipitation patterns.

2. What is the Trewartha Climatic Classification?

The Trewartha Climatic Classification is another system for classifying climates, developed by American geographer Glenn Thomas Trewartha in the mid-20th century. This classification system also takes into account temperature and precipitation patterns but places more emphasis on the impact of temperature on human comfort. It divides climates into six main groups (tropical, arid, warm temperate, snow, polar, and temperate) and further subgroups based on variations in temperature and precipitation.

3. What is the Trewartha Climatic Classification of India?

The Trewartha Climatic Classification of India is a specific application of the Trewartha Climatic Classification system to the climate zones of India. It divides India into seven main climatic regions: tropical wet, tropical wet and dry, arid, semiarid, humid subtropical, subtropical highland, and mountain. This classification takes into account the unique climatic characteristics of India, such as the influence of the monsoon and the diverse topography.

4. What are the Frequently Asked Questions (FAQs) of Koppen's, Thornthwaite's & Trewartha's Classification of World's Climate?

The frequently asked questions related to Koppen's, Thornthwaite's, and Trewartha's classification of the world's climate could include: 1. How do Koppen's, Thornthwaite's, and Trewartha's classification systems differ from each other? 2. What are the main factors considered in each classification system? 3. How do these classification systems help in understanding global climate patterns? 4. Are there any limitations or criticisms of these classification systems? 5. How are these classification systems used in various fields, such as agriculture, urban planning, or climate change research?

5. What are the answers to the Frequently Asked Questions (FAQs) of Koppen's, Thornthwaite's & Trewartha's Classification of World's Climate?

The answers to the frequently asked questions could be provided based on the information given in the article, such as: 1. Koppen's, Thornthwaite's, and Trewartha's classification systems differ in terms of the factors they emphasize, the number of climate groups and subgroups, and the specific applications. 2. The main factors considered in these classification systems include temperature, precipitation, and their seasonal variations. 3. These classification systems help in understanding global climate patterns by providing a standardized framework for categorizing and comparing climates across different regions. 4. Some limitations or criticisms of these classification systems include their simplicity, reliance on long-term averages, and difficulty in accurately classifying transitional or complex climate zones. 5. These classification systems are used in various fields to inform decision-making, such as agricultural planning, water resource management, and assessing the potential impacts of climate change on different regions.

Hydrological Cycle

- Hydrological cycle is also known as “water cycle” and there is a continuous exchange of water between the atmosphere, the oceans and the continents through the processes of evaporation, transpiration, condensation and precipitation. As the moisture which is present in the atmosphere is taken from water bodies through a process called evaporation and from plants through a process called transpiration (evapotranspiration). Further this evaporation undergoes condensation for the formation of clouds and once after the formation of clouds they fall down in the form of raindrops through precipitation process.
- As the total amount of water vapour present in the atmosphere is constant, to maintain this there should be a proper balance between evapotranspiration and precipitation. And the cycle which maintains this stability is the Hydrological cycle.
- This cycle does not have any starting and ending point, as it leads to continuous circulation of water present on the Earth which causes evolution of the Earth. The factor

that assists hydrological cycle or water cycle is the sun, air currents to name a few.

Process of the Water Cycle

Water cycle is completed in various stages or process they are:

Stage I: Evaporation and Transpiration:

In this process energy from the sun heats up the lakes, rivers, oceans, swamps and other water bodies which subsequently increase the temperature of the water present in them. This leads to evaporation of some water into air and the rising air current takes the vapour up in the sky.

Along with this process at the same time plants and trees also lose water to the atmosphere in the form of vapour which rises up in the sky.

Stage II: Condensation

In this process the vapour which rises up gets cooled because of cooler temperature in the surrounding. Because of this water vapour turns back into liquid through the condensation process.

Stage III: Precipitation

In this process there occurs collisions in the cloud particles because of wind movements. Because of this clouds become water laden and they develop into rain bearing clouds and fall back onto the earth's surface by the process known as precipitation.

They may fall on the Earth in the form of rain, hail, snow or sleet depending upon the temperature conditions.

Stage IV: Runoff and Infiltration

After the precipitation process, precipitated water runs off into oceans, rivers and ground surface or is absorbed into the soil (infiltration).

After going through all these steps water is again ready to go through evaporation and resume earlier stages.

By going through all these processes of hydrological cycle or water cycle water is bringed back to people in the form of fresh water.

1. What is the hydrological cycle?

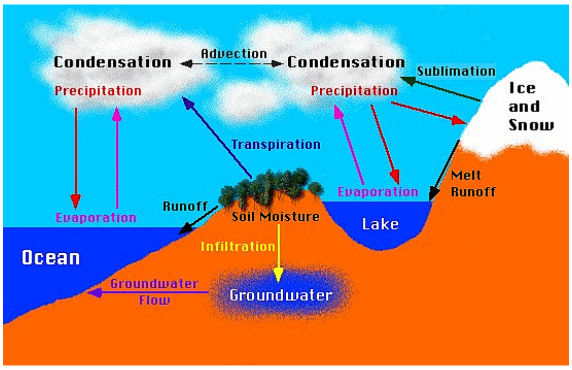
Ans. The hydrological cycle, also known as the water cycle, refers to the continuous movement of water on, above, and below the Earth's surface. It involves processes such as evaporation, condensation, precipitation, and runoff, which help in the distribution and circulation of water across the planet.

2. How does evaporation contribute to the hydrological cycle?

Ans. Evaporation is a crucial process in the hydrological cycle. It occurs when water from oceans, lakes, rivers, or other water bodies is heated by the sun and transforms into water vapor, which rises into the atmosphere. This water vapor then condenses to form clouds and eventually falls back to the Earth's surface as precipitation, completing the cycle.

3. What is the role of precipitation in the hydrological cycle?

Ans. Precipitation plays a vital role in the hydrological cycle as it is the primary way water returns from the atmosphere to the Earth's surface. It includes various forms such as rain, snow, sleet, or hail. Precipitation replenishes water bodies, provides water for plants and animals, and contributes to the overall balance of water on Earth.



Water Vapour in Atmosphere

Volume of water vapour varies in the atmosphere from zero to four per cent by volume of the atmosphere i.e. on an average approx 2% in the atmosphere. Hygrometer is the instrument which is used to measure the amount of water vapour i.e. humidity in the atmosphere.

Significance of Atmospheric Moisture

- Radiation is absorbed by water in both incoming and terrestrial form and by this it plays a crucial role in increasing the heat of the Earth surface.
- The quantity of energy stored in the atmosphere for the development of storms and cyclones is decided by the amount of water vapour present in the atmosphere.
- Rate of human body cooling capacity by the deviation in temperature is influenced by atmospheric moisture.

Humidity

Amount of water vapour present in the air or atmosphere is known as Humidity. The term humidity is explained by relative humidity as a percentage of the maximum amount of water vapor the air can hold at the same temperature.

4. How does the hydrological cycle impact the availability of freshwater resources?

Ans. The hydrological cycle is essential for the availability of freshwater resources. As water evaporates from oceans and other water bodies, it leaves behind impurities, resulting in the formation of freshwater. This freshwater is then transported through the atmosphere in the form of clouds and eventually precipitates onto land, replenishing freshwater sources such as rivers, lakes, and groundwater.

5. What are the consequences of disruptions in the hydrological cycle?

Ans. Disruptions in the hydrological cycle can have severe consequences. For example, excessive deforestation can reduce evaporation, leading to decreased rainfall and drought in the affected area. Similarly, global warming can intensify evaporation and precipitation patterns, leading to more frequent and severe weather events like floods and storms. It is crucial to maintain the balance of the hydrological cycle to ensure the sustainable availability of water resources.

Tricellular Meridional Circulation of the Atmosphere

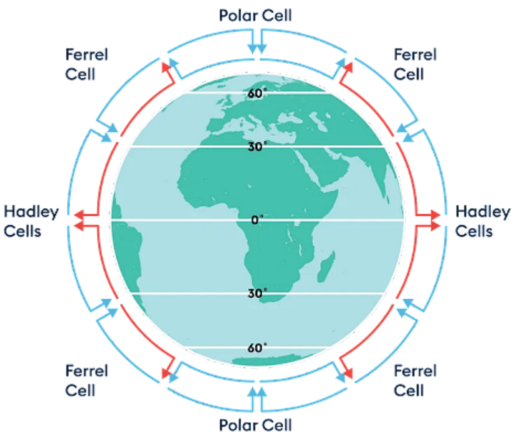
A three cell model of meridional atmospheric circulation, also known as tricellular meridional atmospheric circulation, in which it is assumed that there is cellular air circulation at each meridian (longitude). The global air circulation can be divided into three cells according to this model. The temperature and kinetic parameters involved with global air circulation have been used to divide these cells.

Atmospheric Circulation

Atmospheric circulation is the large-scale movement of air that, along with ocean circulation, is used to redistribute thermal energy throughout the Earth's surface.

Tricellular Atmospheric Model

- The meridional circulation of the atmosphere is explained by the tricellular model.
- The global air circulation can be divided into three cells according to this model.
- The temperature and kinetic parameters involved with global air circulation have been used to divide these cells.



Hadley cell

- In both hemispheres, the cell is found between 10 and 30 degrees latitude.
- This is a solar cell that has been thermally induced as a result of high solar insolation.
- Along the equator, rising air is caused by high insolation.

- The ascending air cools below the tropopause and forms the anti-trade wind, which blows away from the pole.
- They lead to upper air about 30 degrees latitude, which sinks and causes subtropical high pressure.
- This cell is completed by the trade wind, which travels from the High Pressure toward the equator.
- It's one of the most stable cells, and it's linked to a tropical monsoon and a desert climate.

Ferrel Cell

- In both hemispheres, this cell stretches from 35 to 60 degrees latitude.
- This is a dynamically generated cell that is thermally indirect.
- Warm air may be seen ascending from the polar front and breaking through near the tropopause in this cell.
- The polar front is more continuous in the middle troposphere, which is the most notable aspect of this cell.
- The tropical and polar front dells both contribute to air subsidence at the horse latitude.
- The westerly wind blowing toward the poleward side completes the circulation on the surface.

Polar cell

- In both hemispheres, it stretches from 65 to 90 degrees.
- This is a thermally direct cell that is at its most powerful in the winter.
- As the easterly wind travels towards the subpolar low, sinking air moves along the poles.
- The easterly and westerly winds collide at the subpolar lows, causing the air to rise and complete the polar cell circulation.

Significance

- It aids in the formation of doldrums, or the inter-tropical Convergence Zone (ITCZ), the world's most important and continuous belt of convergence.
- The Hadley cell's air circulation manifests itself in the world's tropical deserts.
- The upper air circulation and the trade wind movement have a significant impact on the monsoon phenomenon.

Conclusion

Meridional circulation is also responsible for the formation of tropical cyclones, temperate cyclones, and anticyclones. Above all, it is crucial to comprehend the global climate. Thus meridional circulation not only is an important phenomenon on our planet earth but also in the UPSC Examination.

1. What is the tricellular meridional circulation of the atmosphere?

Ans. The tricellular meridional circulation refers to the three-cell circulation pattern in the Earth's atmosphere. It consists of the Hadley cell near the equator, the Ferrel cell in the mid-latitudes, and the Polar cell near the poles. These cells play a vital role in redistributing heat and moisture across the globe through vertical and horizontal air movements.

2. How does the tricellular meridional circulation influence global weather patterns?

Ans. The tricellular meridional circulation plays a crucial role in shaping global weather patterns. It helps transport heat from the equator towards the poles, creating the trade winds and prevailing westerlies in the process. The rising and sinking air within the cells also contribute to the formation of high and low-pressure systems, influencing the formation of weather systems such as cyclones and anticyclones.

5. Are there any variations in the tricellular meridional circulation on different timescales?

Ans. Yes, variations in the tricellular meridional circulation can occur on different timescales. Natural climate phenomena like the El Niño-Southern Oscillation (ENSO) and the North Atlantic Oscillation (NAO) can result in temporary disruptions to the circulation patterns. Additionally, long-term climate cycles, such as the Milankovitch cycles, can influence the strength and positioning of the circulation cells over thousands of years, affecting global climate patterns.

3. What are the factors that affect the strength and intensity of the tricellular meridional circulation?

Ans. Several factors influence the strength and intensity of the tricellular meridional circulation. These include the temperature gradient between the equator and poles, the Coriolis effect, land-sea distribution, topography, and atmospheric disturbances such as El Niño and La Niña. Any changes in these factors can disrupt the balance of the circulation and lead to alterations in weather patterns.

4. How does the tricellular meridional circulation impact climate change?

Ans. The tricellular meridional circulation is closely linked to climate change. As global temperatures rise due to greenhouse gas emissions, the temperature gradient between the equator and poles is expected to change. This can potentially alter the strength and position of the circulation cells, leading to shifts in precipitation patterns, changes in storm tracks, and modifications in regional climate regimes.

Global Climate Change

Since Greta Thunberg began her protest in front of the Swedish Parliament in August 2018, numerous "climate strikes" have taken place across the globe. However, these protests and the increasing occurrence of extreme weather events, such as unpredictable monsoons, prolonged droughts, and frequent cyclones, have not yet spurred global leaders to take significant action to address climate change. In the Global Climate Risk Index 2021, released by the environmental think tank Germanwatch, India was ranked as the seventh worst-affected country in 2019. If urgent measures are not implemented, the upcoming decade may become increasingly perilous due to uncontrolled and accelerated climate change.

What is climate change?

- Climate change refers to the long-term alteration of Earth's climate due to changes in the atmosphere and the interactions between the atmosphere and various other geological, chemical, biological, and geographical factors within the Earth's system. It can lead to unpredictable weather patterns, which can have significant impacts on agriculture, especially in countries that rely heavily on farming, such as India.
- One of the consequences of climate change is the increasing frequency and intensity of extreme weather events, such as hurricanes, floods, and cyclones. These events can cause widespread damage and devastation.
- Another major impact of climate change is the accelerated melting of polar ice due to rising global temperatures. This leads to rising sea levels, which in turn results in increased flooding and erosion of coastlines.
- The primary cause of the current rapid climate change is human activity, such as the burning of fossil fuels and deforestation. These actions are putting the survival of humanity at risk by contributing to the ongoing and potentially irreversible changes to our planet's climate.

What are the factors that cause climate change?

Climate change is caused by both natural and anthropogenic factors, with human activities having a more significant impact on contemporary climate change.

- **Natural Factors:** Various natural factors contribute to Earth's climate change, affecting the climate over thousands to millions of years.
- **Continental Drift:** Continents today were not the same as they were 200 million years ago. They were formed when the Earth's landmass began to drift apart due to plate displacement. This movement affected climate change by altering the physical features and positions of landmasses and water bodies, such as ocean currents and winds. The drifting of landmasses continues today, with the Himalayan range rising approximately 1 millimeter every year as the Indian landmass moves towards the Asian landmass.
- **Variation of the Earth's Orbit:** The Earth's orbit influences the seasonal distribution of sunlight reaching the Earth's surface. Even a slight change in the Earth's orbit can cause variations in distribution worldwide. While there are minimal changes to average sunshine, this factor greatly impacts the geographical and seasonal distribution. There are three types of orbital variations – variations in Earth's eccentricity, variations in the tilt angle of Earth's axis of rotation, and precession of Earth's axis. These factors together can cause Milankovitch cycles, which significantly impact the climate and are known for their connection to glacial and interglacial periods. The Intergovernmental Panel on Climate Change has found that Milankovitch cycles have influenced ice formation behavior.
- **Plate Tectonics:** Temperature changes in the Earth's core create mantle plumes and convection currents that force Earth's plates to adjust, leading to the rearrangement of Earth's plate. This process can influence global and local climate and atmospheric patterns. Since the position of continents determines the geometry of oceans, their location affects ocean patterns and the global climate. The position of the sea also plays a critical role in controlling heat and moisture transfer across the globe. A recent example of tectonic control on ocean circulation is the formation of the Isthmus of Panama about 5 million years ago, which prevented the direct mixing of the Atlantic and Pacific oceans.
- **Volcanic Activity:** Volcanic eruptions release gases and dust particles that partially block sunlight, leading to a cooling effect on the climate. Although volcanic activities may last only a few days, the gases and ashes they release can persist for extended periods and influence climate patterns. Sulfur oxide emitted by volcanic activities can combine with water to form tiny droplets of sulfuric acid, which can remain in the air for several years.
- **Ocean Currents:** Ocean currents are a major component of the climate system. They are driven by horizontal winds that cause water movement against the sea surface. The temperature differences in the water significantly influence the climate of a region.

Anthropogenic Factors:

Scientists, since the beginning of the 20th century, have studied the impact of climate change caused by human activities. Global warming, the long-term rise in the average temperature of the Earth’s climate system, is a major aspect of climate change. It is mainly a human-caused increase in global surface temperature. The anthropogenic factors causing climate change are as follows:

1. **Greenhouse Gases:** Greenhouse gases (GHGs) absorb heat radiation from the sun. Since the Industrial Revolution, the emission of GHGs into the atmosphere has increased dramatically, causing more heat to be absorbed and retained in the atmosphere, leading to a rise in global temperature. While these gases do not absorb much solar radiation, they do absorb most of the

infrared emitted by Earth's surface. The main greenhouse gases are water vapor (the most abundant GHG but with a lesser impact), carbon dioxide (CO_2), chlorofluorocarbons (CFCs), methane, and nitrous oxide. The concentration of CO_2 has increased by 30% since the start of the industrial revolution, with deforestation also contributing to this increase.

2. **Changes in Land Use Patterns:** Around half of the land-use changes occurred during the industrial era, with forests being replaced by agricultural crops and grazing lands. Deforestation has led to an increase in albedo (the reflectivity of an object in space), particularly in snow-covered regions, resulting in the cooling of the planet's surface. Tropical deforestation also affects evapotranspiration rates (the amount of water vapor released into the atmosphere through evaporation and transpiration from trees), leading to desertification and changes in soil moisture characteristics. Satellite imagery shows that clearing forest cover for agriculture and irrigation in arid and semi-arid areas can increase solar energy absorption and the amount of moisture evaporated into the atmosphere.
3. **Atmospheric Aerosols:** Atmospheric aerosols can scatter and absorb solar and infrared radiation, alter the microphysical and chemical properties of clouds, and directly affect climate change by absorbing or reflecting solar radiation. They can also have indirect effects by modifying cloud formation and properties. Aerosols can be transported thousands of kilometers away from their source through wind and upper-level atmospheric circulation. There are two types of aerosols: natural and anthropogenic (human-caused). Natural aerosols come from sources such as volcanic eruptions and biogenic sources like plankton, while anthropogenic aerosols are produced by activities like burning coal and oil, industrial processes, vehicle emissions, and burning biomass. The concentration of aerosols is about three times higher in the Northern Hemisphere than in the Southern Hemisphere, leading to a 50% higher radiation concentration in the Northern Hemisphere.

What is the primary cause of the current rapid climate change?

A. Variation of the Earth's orbit
B. Human activity
C. Tectonic plate movements
D. Natural factors

What are the effects of climate change?

A rise in atmospheric temperature:

- Human activities are causing an increase in the release of greenhouse gases, which in turn is leading to a rise in Earth's temperature. The last six years have been the hottest ever recorded, illustrating the severity of the issue. This increase in temperature is significantly contributing to a rise in heat-related deaths and illnesses, higher sea levels, and a greater intensity of natural disasters.
- During the 20th century, Earth's average temperature increased by 1°F, which is thought to be the most rapid rise in the past millennium. If greenhouse gas emissions are not reduced, research suggests that the average surface temperature could increase by 3-5°F by the end of the century.

Change in landscapes:

- Rising temperatures and alterations in climate and weather patterns worldwide have caused trees

and plants to shift towards Polar Regions and mountains. As vegetation adapts to these changes by relocating to colder areas, the animals that rely on them for survival are forced to follow suit.

- Although some may successfully adapt, many will likely perish in the process. Species like polar bears, which depend on cold environments, face significant risks to their survival as their habitats are threatened by melting ice. Consequently, the rapid transformation of the Earth's landscape poses a considerable threat to the existence of numerous species, including humans.

A risk to the ecosystem:

- Global temperature increases are causing alterations in weather and vegetation patterns, forcing many species to migrate to cooler regions for survival.
- This situation presents a significant risk to the survival of countless species. If the current trend persists, it is estimated that by 2050, a quarter of the planet's species could face extinction.

Rising sea levels:

- An increase in Earth's temperature contributes to a rise in sea levels due to thermal expansion, a phenomenon where warmer water occupies more space than cooler water. Additionally, the melting of glaciers further exacerbates this issue. Populations residing in low-lying regions, islands, and coastal areas are at risk from these rising sea levels.
- As a result, shorelines erode, properties sustain damage, and vital ecosystems such as mangroves and wetlands, which provide protection against storms, are destroyed. Over the past century, sea levels have risen between 4 and 8 inches, and it is projected that they will continue to rise between 4 and 36 inches in the next 100 years.

Ocean Acidification:

- The rising concentration of CO2 in the atmosphere has led to a higher absorption of CO2 by the ocean. This, in turn, causes the ocean's acidity to increase.
- Many marine species, such as plankton and mollusks, are negatively affected by this increase in ocean acidification. Coral reefs are particularly vulnerable, as the increased acidity makes it challenging for them to form and maintain the skeletal structures essential for their survival.

Increase in the risk of natural and manmade disasters:

- The risk of natural and manmade disasters is increasing due to various factors, such as high atmospheric temperatures that lead to rapid evaporation of moisture from land and water sources. This results in droughts, which make affected areas more vulnerable to the detrimental effects of floods. As a consequence, droughts may become more frequent and severe, leading to negative impacts on agriculture, water security, and human health.
- Countries in Asia and Africa are already experiencing this phenomenon, with droughts becoming increasingly prolonged and intense. Moreover, the rise in temperature is not only causing droughts but also leading to a higher incidence of forest fires worldwide.
- Climate change is further contributing to the increased frequency and intensity of hurricanes and tropical storms, which have disastrous effects on both human societies and the environment. This is due to the warming of ocean waters, as warmer waters fuel the energy of hurricanes and tropical storms.

The other factors that cause intensified hurricane and tropical storms are raising sea levels,

disappearing wetlands and increased coastal development.

Health issues:

- Global warming poses significant health risks, as increased temperatures can lead to more deaths and illnesses. One example of this is the rise in heatwaves caused by climate change, which has already resulted in numerous fatalities. In 2003, for instance, extreme heatwaves claimed the lives of over 20,000 people in Europe and more than 1,500 people in India.
- Moreover, climate change has the potential to exacerbate the spread of infectious diseases, as warmer temperatures allow disease-carrying organisms such as insects, animals, and microbes to survive for longer periods. As a result, diseases and pests that were previously limited to tropical regions may now be able to thrive in areas that were once too cold for them.
- The increasing number of deaths due to extreme heat, natural disasters, and diseases can be linked to climate change. The World Health Organization (WHO) estimates that, between 2030 and 2050, climate change could lead to approximately 250,000 additional deaths per year, resulting from malnutrition, malaria, diarrhea, and heat-related illnesses.

Economic impacts:

- Experts estimate that if no action is taken to reduce carbon emissions, climate change could result in a loss of 5 to 20% of the annual global GDP. In comparison, investing just 1% of GDP could significantly mitigate the most damaging effects of climate change.
- As climate change alters shoreline habitats, there may be a need to relocate ports and near-shore infrastructure, which could cost millions of dollars. Additionally, the increase in hurricanes and other natural disasters could lead to extreme economic losses due to property damage and infrastructure destruction.
- Longer droughts and higher temperatures caused by climate change can lead to reduced crop yields, potentially resulting in starvation for thousands of people. Coral reefs, which generate around $375 billion per year in goods and services, are also under threat due to climate change, affecting economies reliant on these ecosystems.

Agriculture productivity and food security:

- Agricultural productivity and food security are closely tied to climate patterns, as crop cultivation relies on solar radiation, favorable temperatures, and rainfall. With the ongoing changes in the climate, agricultural productivity, food supply, and food security have been significantly impacted. These effects can be observed in biophysical, ecological, and economic aspects.
- As a result of climate change, agricultural and climate zones have been shifting towards the poles. This has led to alterations in agricultural production patterns due to increased atmospheric temperatures. Additionally, agricultural productivity has experienced growth due to the rise in CO_2 levels in the atmosphere.
- However, the unpredictability of precipitation patterns has created challenges for agriculture. This unpredictability has increased the vulnerability of landless and impoverished populations who rely heavily on agriculture for their livelihoods and sustenance.

How is climate change affecting India?

- Climate change poses a significant threat to India due to its diverse terrain, rapid urbanization, industrialization, and economic growth. As the

country strives to protect its diminishing natural resources, it faces environmental and socio-economic challenges, including worsening water and air quality due to pollution. Coastal ecosystems, biodiversity, and agricultural productivity are particularly vulnerable to climate change.

- The increasing frequency and intensity of natural disasters negatively impact India's economy, leading to poverty, vulnerability to diseases, and loss of income and livelihoods. According to the World Bank, a 2°C increase in the world's average temperature in the coming decades will make India's monsoon patterns more unpredictable. This will result in some areas experiencing floods, while others face water scarcity.
- India's agriculture sector, which over 60% of the population relies on for survival, is heavily dependent on rainfall, making the country more susceptible to climate change. By the 2050s, it is estimated that a 2-2.5°C temperature increase will reduce water availability in the Indus, Ganges, and Brahmaputra river basins, threatening the food security of approximately 63 million people.
- The rate of poverty reduction will also slow down due to rising atmospheric temperatures, with the poor being more vulnerable to climate change as they often rely on rain-dependent agriculture. An increase of 2°C by the 2040s is expected to impact crop production, reducing output by 12% and necessitating more imports to meet domestic demands. In addition, the decreasing availability of food may lead to significant health issues, particularly among women and children.
- Lastly, the melting glaciers and loss of snow pose a risk to reliable water resources in India. Major rivers such as the Ganges, Indus, and Brahmaputra primarily depend on snow and glacial meltwater, making them vulnerable to global warming.

What are the efforts taken at the international level to combat climate change?

Intergovernmental Panel on Climate Change (IPCC)

- The Intergovernmental Panel on Climate Change (IPCC) was established by the World Meteorological Organisation (WMO) and the UN Environment Programme (UNEP) to create a platform for governments to study the impacts of global warming collectively.
- As a United Nations entity, the IPCC is dedicated to evaluating the scientific research associated with climate change. It regularly supplies policymakers with comprehensive assessments of climate change, its consequences, and possible future risks, while also offering options for adaptation and mitigation.
- In this way, the IPCC works in harmony with the United Nations Framework Convention on Climate Change (UNFCCC) to address the global challenge of climate change.

United Nations Framework Convention on Climate Change (UNFCCC):

- The United Nations Framework Convention on Climate Change (UNFCCC) is an international environmental treaty that was enforced on March 21, 1994. It has been ratified by 195 countries, which are referred to as the Parties to the Convention. The UNFCCC is one of three Rio Conventions adopted at the 1992 Rio Earth Summit, alongside the UN Convention on Biological Diversity and the UN Convention to Combat Desertification. To ensure cooperation among these conventions, the Joint Liaison Group was established, which also includes the Ramsar Convention on Wetlands.
- The primary goal of the UNFCCC is to stabilize the concentration of greenhouse gases in the atmosphere to prevent dangerous human-induced interference with the climate system. It aims to achieve this target within a specific timeframe, allowing ecosystems to naturally adapt to climate change while maintaining food security and supporting sustainable economic development.
- Following the establishment of the UNFCCC, the first Conference of Parties (COP1) was held in Berlin, the second (COP2) in Geneva, and the third (COP3) in

Kyoto. The Kyoto Protocol was adopted during COP3 to ensure the implementation of the UNFCCC's objectives.

Kyoto Protocol:

The Kyoto Protocol was adopted on December 11, 1997, in Kyoto, Japan, and came into effect on February 16, 2005. This international treaty commits its signatories to reducing greenhouse gas (GHG) emissions, holding developed countries responsible for the current high levels of emissions due to their historical role in the industrial revolution.

- The 7th Conference of the Parties (COP 7) took place in Morocco in 2001, and the detailed rules for implementing the Kyoto Protocol were adopted, known as the "Marrakesh Accords." The Kyoto Protocol also established a Flexible Mechanism, or Kyoto Mechanism, to reduce the overall cost of achieving emission reduction targets. This mechanism includes Emission Trading, the Clean Development Mechanism, and Joint Implementation.

In December 2012, the Doha Amendment to the Kyoto Protocol was adopted, introducing several changes:

- New commitments were made by Annex I Parties (developed countries and Economies in Transition) for the period from January 1, 2013, to December 31, 2020.
- A revised list of GHGs that Parties must report during the second commitment period was established.
- Several articles of the Kyoto Protocol were updated to align with the second commitment period.

Overall, the Kyoto Protocol represents a critical step towards reducing global emissions and stabilizing GHG levels in the atmosphere.

Paris Agreement:

- The Paris Agreement, signed in 2016, is the world's first comprehensive climate accord, aiming to keep global temperatures well below 2°C above preindustrial levels and further limiting them to 1.5°C. It seeks to enhance nations' capacity to fight the negative effects of climate change and requires the reduction of greenhouse gas (GHG) emissions from human activities to levels that can be naturally absorbed by trees, soil, and oceans.
- Under the Agreement, countries must review their efforts to cut emissions every five years. It also mandates that wealthier nations provide financial support to help developing countries transition to renewable energy sources. While some aspects of the agreement are binding, such as reporting requirements, individual countries' emission targets are not.
- The Paris Agreement requires all participating countries to put forth their best efforts through Nationally Determined Contributions (NDCs) and to continually enhance these efforts. This includes regular reporting on emissions and implementation progress.
- India's Intended Nationally Determined Contribution (INDC) commits to reducing its GDP's emissions intensity by 33-35% by 2030 compared to 2005 levels. The country has also pledged to increase non-fossil fuel-based electricity's share to 40% by 2030 and expand its forest cover to absorb 2.5-3 billion tonnes of CO_2 by the same year.

REDD+

- Reducing Emissions from Deforestation and Forest Degradation (REDD) is a strategy developed by the United Nations Framework Convention on Climate Change (UNFCCC) to address climate change. This mechanism assigns a monetary value to the carbon stored in forests, providing financial incentives for developing countries to reduce emissions from forested areas and invest in sustainable, low-carbon development initiatives. These countries receive payments based on their efforts to reduce emissions and promote sustainable forest management.
- REDD encompasses more than just preventing deforestation and forest degradation; it also includes conservation efforts, sustainable forest management, and enhancing forest carbon stocks. It is estimated that the financial support provided through REDD for reducing greenhouse gas emissions could amount to as much as $30 billion per year.
- This increased flow of funds from developed to developing countries can significantly contribute to reducing carbon emissions while promoting inclusive development. Additionally, it has the potential to improve biodiversity conservation and protect essential ecosystem services. Forests play a critical role in

absorbing carbon dioxide, making it crucial to enhance their resilience to climate change.

What are the measures taken by the Indian government to combat climate change?

- India is the fifth-largest emitter of greenhouse gases (GHGs), contributing to approximately 5% of global emissions. Between 1990 and 2005, India's emissions increased by 65%, and they are expected to rise by another 70% by 2020. India is highly vulnerable to climate change due to increased natural disasters, depleting natural resources, and its strong dependence on agriculture and rainfall.
- Despite these challenges, India is taking several measures to adapt to and mitigate climate change. These include increasing energy efficiency, promoting a circular economic model, and encouraging the use of renewable energy. India is among the few countries that have increased the Clean Energy Cess on coal, and it has established a Clean Energy Fund worth approximately $3 billion to promote clean technologies.
- The Indian government is also investing in afforestation to increase the country's carbon sink. India has set a target of having 33% of its geographical area covered by forests. According to the biennial State of India's Forest Report 2019, the country's total forest cover is currently 21.67% of its total geographical area.
- Additionally, India has allocated about $200 million for the National Adaptation Fund for Climate Change (NAFCC). This initiative aims to support activities that can mitigate the adverse effects of climate change. Projects funded by the NAFCC focus on adaptation in sectors such as agriculture, animal husbandry, water, forestry, and tourism. These projects are implemented in a project mode to ensure efficient and targeted use of resources.

Other initiatives include 100 smart cities, National Mission for Clean

National Action Plan on Climate Change (NAPCC)

As a part of the NAPCC, the Indian government had launched 8 missions on focused areas. They are:

- National Solar Mission
- National Mission for Enhanced Energy Efficiency
- National Mission on Sustainable Habitat
- National Water Mission
- National Mission for Sustaining the Himalayan Ecosystem
- National Mission for a “Green India” Goals
- National Mission for Sustainable Agriculture
- National Mission on Strategic Knowledge for Climate Change

National Action Programme to Combat Desertification:

- India is one of the parties of UNCCD.
- The Ministry of Environment, Forest and Climate Change is the National Coordination Agency for the implementation of the UNCCD at the national level.
- India has framed the 20-year comprehensive National Action Programme (NAP) to address the problem of desertification within the nation. The objectives include:
- Drought management, preparedness, and mitigation
- Development based on a community approach
- Promote the improvement of local communities’ quality of life
- Promote awareness
- Promote suitable research and development initiatives and interventions.
- Promoting self-governance to empower local communities so that they can deal with issues pertaining to climate change.

India in the international forums on climate change:

- India is currently setting up voluntary targets in the international forums to commit itself to the mission to combat climate change. It is also playing a major role in climate change mitigation.
- India's proactive role in mitigating climate change is due to the domestic compulsion of tackling issues like the need for poverty eradication, food and nutritional security, universalization of health and education, water security, sustainable energy, employment
- India is of the opinion that the developing countries' need for inclusive growth, sustainable development, poverty eradication and universal access to energy must be made the fundamental differentiation between them and the developed nations. Currently, the Conventions recognise that the historical emissions of the developed nations as the basis for differentiation between the developed and developing nations.

What is stopping us from mitigating climate change?

Several barriers are hindering our ability to effectively address climate change. According to the 5th Assessment Report of the IPCC, these economic barriers include:

- **Transitional costs:** These are the expenses involved in acquiring information and adjusting to new conditions, such as replacing long-lived capital.
- **Market failures and missing markets:** This refers to situations where externalities, information asymmetries, and moral hazards exist. These issues arise when one economic entity harms another or when there are insufficient incentives for change.
- **Behavioral obstacles:** Irrational decisions, social norms, and cultural factors can also impede adaptation efforts.
- **Ethical and distributional issues:** Decisions may be constrained by ethical considerations or differences in vulnerability and adaptive capacity.
- **Coordination, government failures, and politics:** Governments should work to overcome the aforementioned barriers, but they may face similar challenges, such as limited knowledge or resources. Additionally, coordinating efforts between various departments can be difficult, and political disputes about the reality of climate change may prevent governments from taking necessary actions.
- **Uncertainty:** A major barrier to adaptation is the uncertainty surrounding future developments in demographics, technologies, economics, and climate change itself.

What is the main goal of the United Nations Framework Convention on Climate Change (UNFCCC)?

A. To reduce global temperatures by 2°C
B. To stabilize the concentration of greenhouse gases in the atmosphere
C. To increase the use of renewable energy sources
D. To promote sustainable economic development

Conclusion

Climate change is a reality that must be acknowledged and not turned into a political issue. Collaborating on a global scale is crucial in order to lessen the negative consequences of climate change. Moreover, it is essential to combine efforts in climate change mitigation with adaptation strategies, as solely focusing on mitigation will not sufficiently address the current negative impacts. A thorough plan of action at the international level is needed to ensure the inclusive and sustainable growth of the global community.

What is climate change, and how does it impact agriculture and extreme weather events?

Climate change refers to the long-term alteration of Earth's climate due to changes in the atmosphere and interactions between the atmosphere and various factors within the Earth's system. It can lead to unpredictable weather patterns, which can significantly impact agriculture, especially in countries that rely heavily on farming, such as India. One of the consequences of climate change is the increasing frequency and intensity of extreme weather events, such as hurricanes, floods, and cyclones, causing widespread damage and devastation.

What factors cause climate change?

Climate change is caused by both natural and anthropogenic (human-caused) factors. Natural factors include continental drift, variation of the Earth's orbit, plate tectonics, volcanic activity, and ocean currents. Anthropogenic factors primarily involve the release of greenhouse gases (GHGs) into the atmosphere due to human activities such as burning fossil fuels, deforestation, changes in land use patterns, and atmospheric aerosols.

How is climate change affecting India?

India is particularly vulnerable to climate change due to its diverse terrain, rapid urbanization, industrialization, and economic growth. The country faces environmental and socio-economic challenges, including worsening water and air quality due to pollution. Coastal ecosystems, biodiversity, and agricultural productivity are under threat from climate change. The increasing frequency and intensity of natural disasters negatively impact India's economy, leading to poverty, vulnerability to diseases, and loss of income and livelihoods.

What international efforts have been taken to combat climate change?

Some key international efforts to combat climate change include the establishment of the Intergovernmental Panel on Climate Change (IPCC), the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol, the Paris Agreement, and the REDD (Reducing Emissions from Deforestation and Forest Degradation) strategy.

What measures has the Indian government taken to combat climate change?

India has taken several measures to adapt to and mitigate climate change, including increasing energy efficiency, promoting a circular economic model, encouraging the use of renewable energy, investing in afforestation, and allocating funds for the National Adaptation Fund for Climate Change (NAFCC). The country has also launched eight focused missions as part of the National Action Plan on Climate Change (NAPCC) to address various aspects of climate change.

1. What is climate change?

Ans. Climate change refers to long-term shifts in weather patterns and average temperatures on Earth. It is primarily caused by human activities such as burning fossil fuels, deforestation, and industrial processes, which release greenhouse gases into the atmosphere. These gases trap heat, causing the Earth's temperature to rise, leading to various environmental and societal impacts.

2. What are the effects of climate change?

Ans. Climate change has a wide range of effects on the planet. It leads to rising global temperatures, melting glaciers and ice caps, sea-level rise, more frequent and severe weather events such as hurricanes and heatwaves, changes in precipitation patterns, and shifts in ecosystems. It also impacts agriculture, water resources, human health, and biodiversity, and can contribute to the spread of diseases.

3. How is climate change affecting India?

Ans. India is highly vulnerable to the impacts of climate change. It experiences extreme weather events such as heatwaves, floods, droughts, and cyclones, which have become more intense and frequent in recent years. These events cause significant damage to infrastructure, agriculture, and livelihoods. Climate change also affects water resources, with changes in rainfall patterns leading to water scarcity in some regions. Rising sea levels pose a threat to coastal areas, including major cities like Mumbai and Kolkata.

4. How does climate change impact agriculture in India?

Ans. Climate change has significant implications for agriculture in India. Changes in temperature and rainfall patterns affect crop yields, leading to reduced productivity and food security challenges. Heat stress, water scarcity, and increased pest and disease pressure further exacerbate these challenges. Small farmers, who constitute a large portion of the Indian population, are particularly vulnerable to these impacts, as they rely heavily on rain-fed agriculture.

5. What measures is India taking to address climate change?

Ans. India has taken several steps to address climate change. It aims to reduce its greenhouse gas emissions intensity by 33-35% by 2030 compared to 2005 levels. The country has increased its renewable energy capacity, particularly in solar and wind power, and has set a target to achieve 450 GW of renewable energy by 2030. India is also implementing measures to enhance energy efficiency, promote sustainable transport, and invest in climate resilience and adaptation measures. Additionally, initiatives like the International Solar Alliance and the Coalition for Disaster Resilient Infrastructure showcase India's commitment to global climate action.